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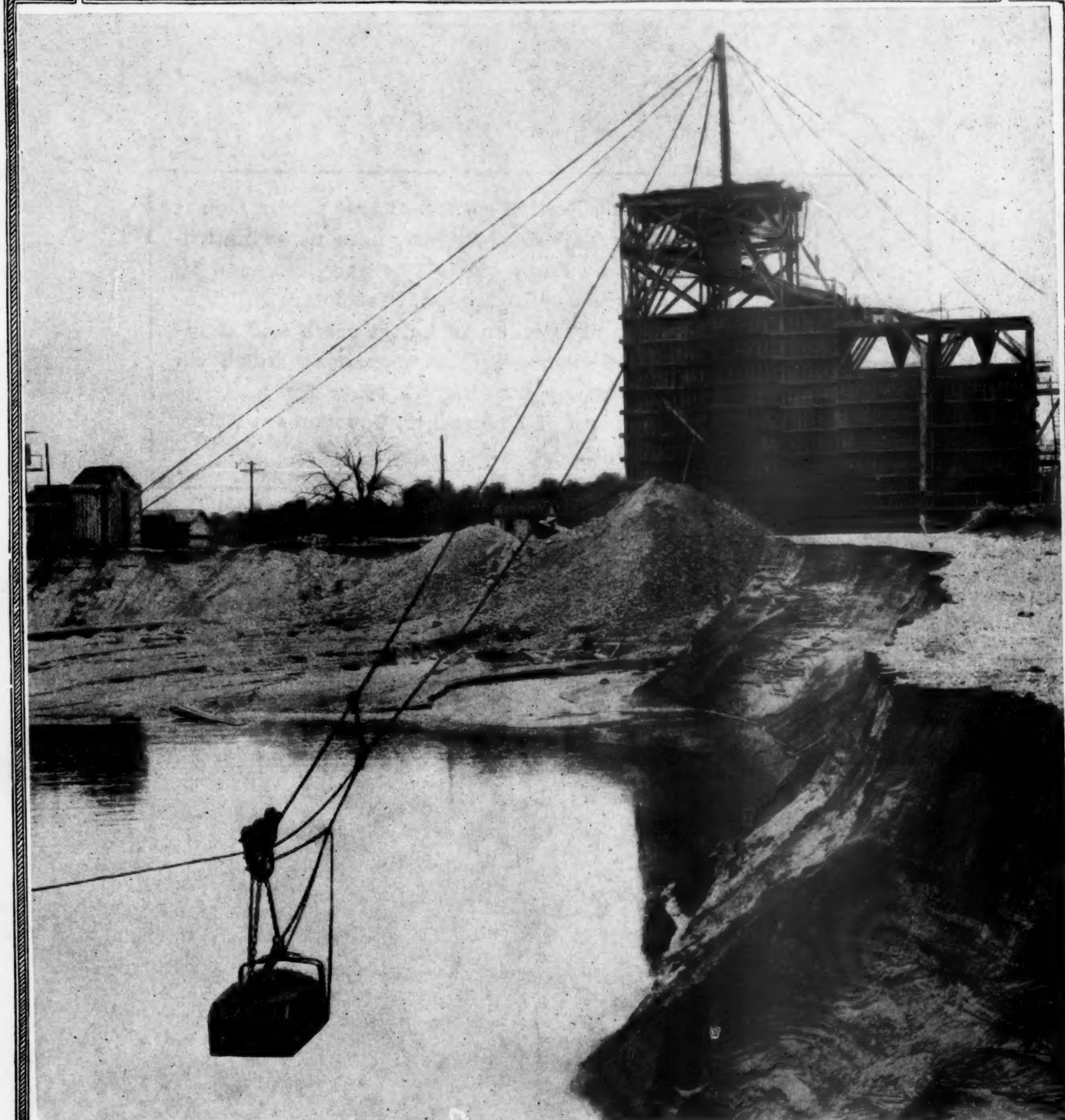

CABLEWAY DRAGLINE IN OPERATION AT ILLINOIS SAND AND GRAVEL PLANT

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1921

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U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

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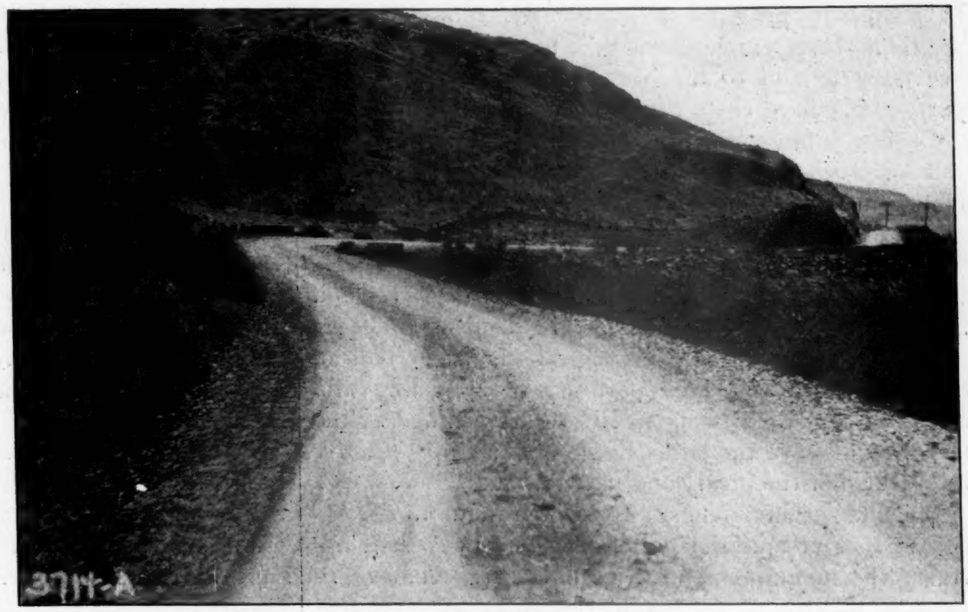
CRUSHED STONE AND GRAVEL ROADS

By C. L. McKESSON, Senior Highway Engineer, and A. F. MORRIS, Highway Engineer, Bureau of Public Roads.

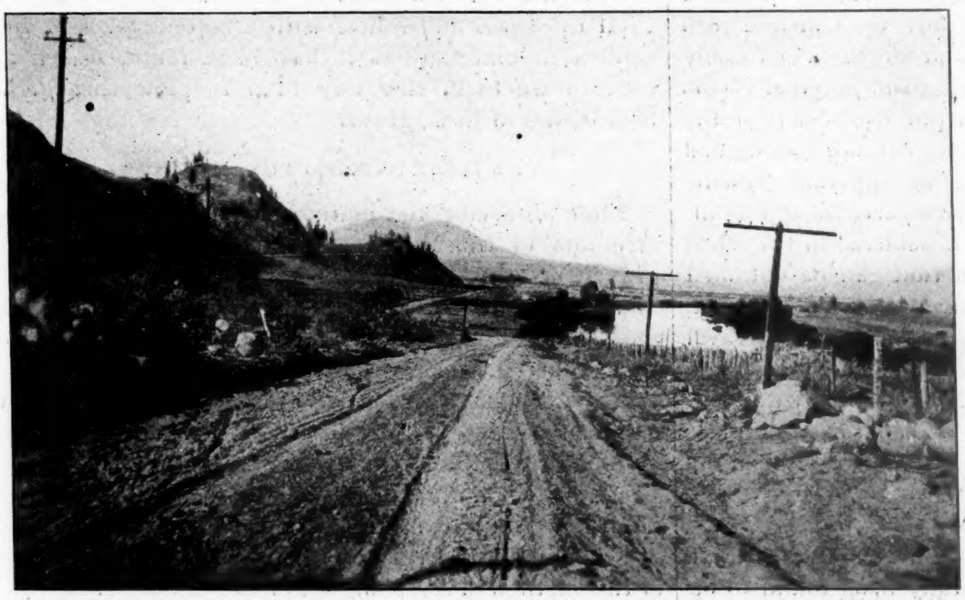


FEDERAL-AID PROJECT NO. 44, IN GILLIAM COUNTY, OREG., SURFACED WITH CRUSHED GRAVEL

THE fact that for many years an extensive mileage of highways must of necessity be surfaced with crushed stone or gravel seems to warrant a review of developments in this type of construction in the Pacific Northwest. This paper does not take into consideration macadam surfacing, which is an altogether different type.

Many miles of crushed stone or gravel surfac ng are now under construction. Due to a lack of water in most localities where this type is being built, water has been used on only a few projects and rolling is seldom resorted to. The general practice now in this section is to use much finer material than heretofore, both in bottom and top courses. The maximum size of material used is 2 inches, and on many of the most satisfactory pieces of construction 1½ inches was fixed as the maximum. The ease with which such a surfacing may be maintained and the smooth, uniform roadway resulting seem to justify the small additional cost involved in producing the finer material.

The more recent specifications for crushed stone or crushed gravel surfacing usually require the material to be screened into two bins, one receiving the material from 2 inches or 1½ inches, the maximum size, down to 1 inch or ⅞ inch, and the other containing the finer material. The material is spread in 2 courses, each approximately one-half of the total thickness, but the exact thickness is regulated in such a way as to use all of the material between 1½ inches and 1 inch (or ⅞ inch) for the bottom course and the finer material for the top course. The base course is usually spread about 500 feet in advance of the top course, but this is varied in order to prevent the overflow of either of the bins.



WASHINGTON FEDERAL-AID PROJECT NO. 14, IN OKANOGAN COUNTY, SURFACED WITH SCREENED GRAVEL

SPECIFICATIONS GIVE SATISFACTORY RESULTS.

The results obtained under these specifications have been satisfactory, but it has been noted that the stone from some quarries has set up into a smooth, hard roadway much more quickly than that from others. In some cases stone

which screening and abrasive tests indicated as being of superior quality did not form as satisfactory road material as a softer stone on which a rather adverse report had been made by the testing engineer. It has been demonstrated that a small amount of soft stone in a quarry provides a binder which is far more desirable than earth or clay, which it is sometimes necessary to add to the base where the material is a particularly hard clean basalt.

On one project in Central Oregon the specifications call for crusher-run material of a maximum size of 1½ inches laid in one course of 5-inch thickness and leveled up with a top course of approximately 1-inch thickness. The results are not as satisfactory as on other projects where the material is separated into two grades and laid in two courses. When laid in deep courses, the material does not compact as well as when laid in lighter courses and the operation of spreading and dragging the stone tends to sift the screenings to the bottom and leave the larger fragments on top—exactly the reverse of the ideal condition.

In some specifications an attempt is made to specify percentages of material passing a series of screens between the maximum and minimum sizes. There appears to be little or no justification in practice for this attempted refinement. A gravel or broken-stone type of surfacing is at best only a light traffic surfacing and every effort should be made to use suitable materials locally available. In many cases splendid pieces of work have been constructed with material which would not comply with a specification requiring an ideal grading with a minimum percentage of voids. The maximum size should be specified at 1½ or 2 inches. The maximum and minimum percentages of sand should be specified between liberal limits. The proportions passing and retained on a ¾-inch or 1-inch screen should also be specified. These proportions can easily be checked on a large scale during the progress of the work by noting the relative output from each of the bins. The various pits should be carefully examined and average grading of the material, apparent cementing qualities, percentage of oversize particles and availability of material should all be considered in the selection of pits. The best material that can be obtained within reasonable costs should always be selected. In some cases it will be found necessary to use gravel little of which is coarser than ¾ inch or 1 inch, and some very satisfactory results have been obtained with such gravel, which of course requires no separation of sizes.

CRUSHED GRAVEL MOST SATISFACTORY FOR DRY-BUILT ROADS.

Where surfacing is laid without water and without rolling, crushed gravel has generally been found to be the most satisfactory material. The selection of gravel pits requires care and experience on the part of the engineer. As a rule any gravel which is found cemented together in the pit will form an excellent road metal when crushed and properly laid, while gravel which lies loose in its natural state, as in beds of streams or which carries a large amount of sand, can not be expected to set up rapidly when deposited on a road, though there have been some exceptions to this rule. The gravel, though lying loose and free in the bank, may carry enough soft granite or other soft stone to form a natural binder when crushed, but as a general rule, unless the material is found well cemented in the pit, it will not prove satisfactory as a surfacing material where the oversize gravel and excess sand is screened out and no crusher used. Such material will not compact into a good wearing surface in dry weather without the addition of clay or earth binder. Where such binder is used the results usually appear to be satisfactory in the summer, but, when the clay which acted as a binder in August becomes a lubricant in January, the results are apt to be far from satisfactory. It is very desirable to crush oversize material rather than to screen and waste it. Any gravel which contains 15 to 20 per cent of oversize material will justify the use of a crusher.

A number of projects have been constructed with gravel spread in two layers each of approximately one-half the total thickness, the material in both the top and bottom courses being required to pass a 1½-inch screen. In Washington it has been the general rule to specify "one-course" gravel of a maximum size of 1½ inches. While the specifications permit laying the total thickness (which varies from 6 to 8 inches) in one course, it has been the general practice to spread a base course of approximately one-half the total thickness and follow with a second layer of the same size material, as it has been found easier to operate trucks in this way than to plow through 6 or 8 inches of loose gravel.

THE MOST SATISFACTORY METHOD.

After observing the methods employed in the construction of the various types of crushed rock and gravel surfacing on many Federal-aid jobs in district 1 and the results obtained, we are convinced that the most satisfactory road surface has been secured where the crushed gravel was placed in two courses; the bottom course consisting of material passing a screen with circular openings of not more than 2 inches, preferably 1½ inches, and retained on a screen having openings of 1 inch or ¾-inch diameter and the top course consisting of all material passing the smaller screen.

There is some difference of opinion as to the merits of this method of screening into two sizes before laying. Some engineers argue that it is better to use crusher run material in both courses on the theory that in this

way the voids in the base are filled better than if the fines are screened out. If it were possible to obtain a uniform mixture and to maintain this uniformity through the various stages of crushing, screening, hauling, and spreading the rock, there would be no doubt that the crusher-run method would be the more desirable, but it is not possible to secure the desired uniformity when all the output of the plant falls into one bin.

When the material falls from the screen, the fines cling together in a pyramid, while the larger pebbles and fragments roll down and outward to the sides of the bin. The result is that some loads hauled to the road contain practically all fines, while others consist almost entirely of the larger size stone; so that the theoretically uniform mixture actually consists of a patch of course and a patch of fine, with the fines on the bottom and the coarse material on top quite as frequently as otherwise, which is exactly the reverse of what it should be.

Even if every load were uniformly graded and mixed when deposited on the road, which they never are, the process of spreading and dragging necessary to secure a true and uniform surface would tend to work the fine material to the bottom, leaving the coarser particles on top, thus again producing a condition exactly opposed to the ideal, which is more nearly obtained by first laying the heavy rock on the bottom and spreading a top course of fine material.

IMPORTANCE OF DRAGGING DURING CONSTRUCTION.

The great importance of constantly dragging and maintaining the surface of the roadway during construction is frequently overlooked. Surfacing is usually begun at the source of supply, so that hauling and trucking of material will be carried on over the newly placed stone until the job is completed. With proper dragging a smooth, uniform surface can be obtained by the time the project is completed, but without dragging the road becomes badly rutted and a rough, unsatisfactory job results. In dragging it has been found advisable to use a light drag in the early stages, gradually filling the ruts as they are formed. If a heavy drag is used which entirely fills the ruts, the trucks are obliged to plow new ruts, and a constant repetition of this operation results principally in an excessive cost for hauling and leaves a poorly compacted surface. With light drags gradually filling the ruts, the ruts are built up and soon traffic can be distributed over the surface.

On one Oregon project it was necessary to truck material over the new surfacing up to a distance of 11 miles from the pit. Without proper dragging or water this job made a very poor showing for several months. Two water tanks were then provided, the gravel was kept damp and dragged with light drags, and the job carried to a most satisfactory completion. The cost for watering in this case was about $250 per mile, but upon completion a smooth and well compacted surface was turned over to the public in spite of the heavy trucking during construction. A blade or road planer is necessary to finish such a surface after it has begun to compact under the light drags.

On one project heavy wagon tires dragged over the ruts behind the trucks assisted in filling and compacting the material and in eliminating the ruts.

The advisability of continuing the practice of laying screened or pit-run gravel surfacing without sprinkling and continuous dragging is seriously questioned, except in the rare instances where water can not be obtained. It is true that in nearly every case a fairly good road surface has been secured after properly maintaining it through a winter, with the usual amount of moisture from rain and melting snow; but it is very seldom that such a surface becomes really satisfactory until it has been thoroughly wet down, either by natural means or by the use of sprinklers in the course of construction.

Where water is available the cost per mile for sprinkling and dragging is usually very small as compared with the satisfaction of having a firm, smooth surface as soon as the road is completed. The inconvenience of a loose, rutty surface for the first season, as is so often the case where water and drag are not used, may thus be avoided. The reduced cost of maintenance for the first year where a road is properly compacted during construction will probably offset the cost of water used.

The illustrations show the difference between a crushed gravel surface and one of screened gravel, both laid without water or rolling and under practically the same weather conditions.

BRITISH ROAD CLASSIFICATION.

The classification of roads under the British ministry of transports' scheme is nearing completion, and when the schedules reach their final form it is the intention of the ministry to distinguish each first and second class road by an individual number. Another feature of the scheme is the standardization of warning signs and road direction posts; provision has been made for indicating the route numbers on the arms of posts in the belief that "the universal adoption of this practice would be of the greatest service to road users generally." These details are included in a letter from the ministry to the highway authorities in England. The letter concludes by saying that Sir Eric Geddes is not advocating "any wholesale replacement of serviceable signs at the present time."

CAPILLARY MOISTURE AND ITS EFFECT ON HIGHWAY SUBGRADES

By W. W. McLAUGHLIN, Senior Irrigation Engineer, Bureau of Public Roads.

ONE of the basic necessities in a pavement is a dry, well drained foundation or subgrade. The prevailing practice is to provide drainage by means of open ditches, covered drains, or both, for the removal of free surface or free ground water. Even where this precaution has been taken, many highway pavements have failed because of wet bases. In other instances, in the arid sections of the country, pavements have at least partially failed where drainage was not thought to be necessary, and these partial failures have resulted, as far as could be determined, because of moisture distribution in the subgrades.

Why do these highways fail? Why do the foundations become wet and unstable in the face of accepted drainage methods? These are live questions bothering many highway engineers and now causing much concern in connection with highway pavement construction.

That capillary moisture may be the cause of some highway troubles and even failures has but recently been suspected. The writer's interest has been aroused in this question by investigations of the movement of soil moisture by capillarity by the division of irrigation investigations of the Bureau of Public Roads. It is the purpose of this article to present briefly a few of the data which may have a bearing upon the subject.

The force of capillarity acts equally in all directions, while the force of gravity acts only in a direction vertically downward. These two forces are at work all the time upon any moisture which may be within the soil. Capillarity is augmented by gravity when working in a direction downward from the horizontal and is reduced by that amount when working in a direction upward from the horizontal.

The following table indicates the relative effects of these two forces:

TABLE NO. 1.—*Capillary movement of soil moisture from a free water surface into a lava ash soil column for various periods of time, and the total quantity of water moved.*

	Time in days.	Direction moisture moved.			
		Vertically upward.	Horizontal.	Downward 15° from horizontal.	Downward 30° from horizontal.
		Inches.	*Inches.*	*Inches.*	*Inches.*
Distance moved	1	16.25	22.9	24.[illegible]	26.20
	2	23.59	30.85	34.05	38.05
	3	27.67	37.55	41.70	42.35
	7	37.42	57.40	63.40	66.25
	15	46.92	81.45	95.25	99.70
	30	54.50	109.90	137.10	150.10
Water moved in acre-inches, per acre	1	0.403	0.605	0.655	0.605
	2	.554	.806	.907	.857
	3	.706	1.008	1.109	1.058
	7	.907	1.562	1.764	1.764
	15	1.169	2.369	2.722	3.024
	30	1.320	3.58	4.334	5.141

The table shows clearly the effect of gravity on the capillary movement of soil moisture, both as to the distance the latter will reach in a given time and the total quantity of water moved. Expressed in round numbers and based upon the figures for the vertical column the moisture had moved downward at the end of 30 days two and one-half times as far in the soil column inclined downward at an angle of 15° and two and three-fourths times as far in the soil inclined downward at an angle of 30°, as it had moved upward in the vertical column. At the end of 30 days, three and one-fourth times as much water had moved down the 15° incline and three and nine-tenths times as much water had moved down the 30° incline as had climbed upward in the vertical column.

The table also shows that the quantity of water per unit over the entire wetted length is greater for the columns inclined downward than for the horizontal or vertical columns. That some idea may be obtained of the unit distribution of moisture in a vertical soil column and in a column inclined downward at an angle of 30° the following table is given:

TABLE NO. 2.—*Distribution of moisture in soil columns by 2-inch sections from the water surface.*

[Yolo gravel-clay loam.]

Distance from water surface.	Percentage of moisture in the soil.	
	Vertical column.	Column inclined downward 30°.
	Per cent.	*Per cent.*
2 inches	37.48	36.03
4 inches	36.72	35.92
6 inches	37.31	35.00
8 inches	37.68	34.39
10 inches	35.85	34.74
12 inches	32.35	34.28
14 inches	30.60	33.61
16 inches	28.20	32.30
18 inches	26.05	31.00
20 inches	23.25	29.94
22 inches	20.18	28.70
Average	31.45	35.99

In the table the average percentage of moisture per inch in the inclined column is greater by 4½ per cent than that in the vertical column. The per cent of moisture in the end of the column away from the body of free water is 42 per cent greater in the inclined column than in the vertical column. This circumstance is of the greatest importance, because the supporting strength of the subgrade depends upon the percentage of water in the soil.

The percentage of moisture found in a vertical soil column is not related directly to the height above the ground water except at the upper end, and then in only a very general way. The maximum percentage of moisture may be found and, in the clays and loams,

usually is found several inches above the water surface. This point is illustrated by figure 1.

From the figure it is seen that in the Riverside soil the greatest per cent of moisture is found about 15 inches above the water surface. In the Idaho lava ash about one-half of the soil column is up to capillary saturation. In other words, there would be little difference from the standpoint of moisture content whether the pavement was 6 inches or 24 inches above the water surface.

EFFECT OF GRAVEL SUB-BASE INDICATED.

Stratified soils of different types are usually found in the alluvial areas and the relative percentage of moisture in the several strata is of interest. Several soil columns were made up of sand, loam, and clay in alternate layers, differently arranged. These columns after having stood for several days were analyzed for moisture. It was found that, at the same height, the several strata contained approximately the same percentage of moisture as a column of one type representing the various soils mingled. Table 3 gives the results of a typical instance. The made-up soil column has 6 inches of clay on the bottom, then 4 inches of river sand, and then a layer of clay, 6 inches thick, of the same type as the bottom layer. The second column of the table gives the percentage of moisture at various heights in a soil column made up as described above, and column 3 gives the percentage of moisture found at the corresponding heights in a uniform soil column of the type found in the made-up column at the respective heights.

TABLE No. 3.—*Distribution of moisture in soil column of uniform type and in a stratified column of different soil types.*

Distance above the water.	Percentage of moisture.	
	Made-up column.	Uniform column.
	Per cent.	*Per cent.*
Average from 0 to 6 inches	44.39	47.95
6 to 10 inches	13.46	16.10
10 to 12 inches	43.52	40.78
12 to 14 inches	14.89	14.21
18 inches	13.72	12.19

In a soil column made up of 16 inches of clay on the bottom and sand on top, the moisture had not moved up into the sand more than 3 inches after standing 20 days. There was only 5 per cent of moisture in the sand, although there was 39 per cent in the top of the clay. Other similar tests indicated the advantage of a top layer of sand or gravel in keeping the moisture percentage low near the upper end of the soil column. The top layer of sand also seems to permit only slow movement of the moisture from the clay upward into the sand. Generally speaking, if the sand or gravel is placed at the bottom and a topping of clay or loam provided, the sand or gravel must be thick enough to prevent the rise of moisture to its upper edge to be effective. While the sand layer may transmit the moisture slowly, the clay or loam will readily take it up. Retardation of the movement within the limits of a few weeks is not of material importance or advantage in pavement work.

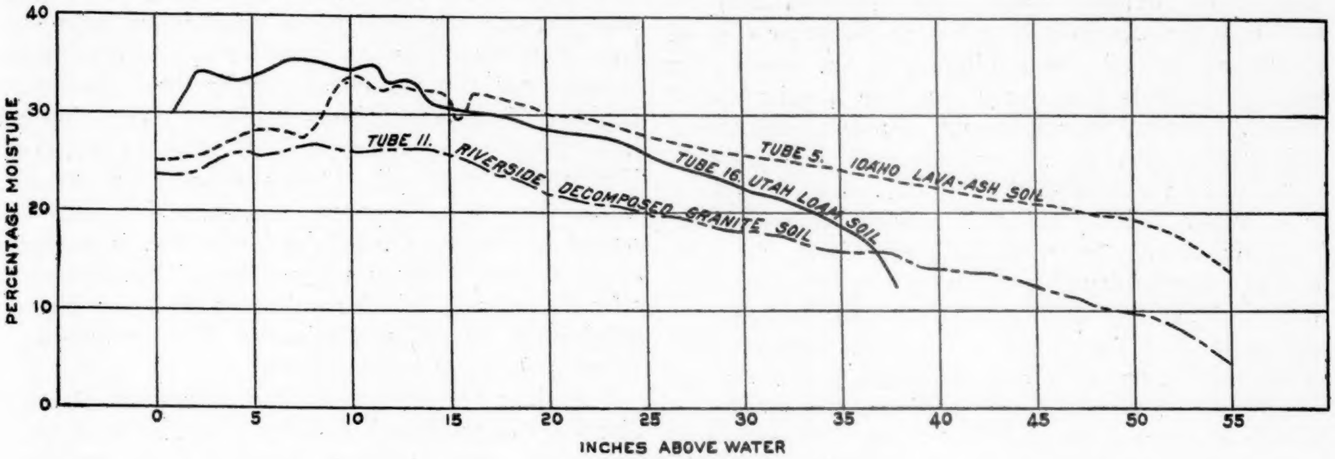


FIGURE 1.

EXTENT AND RATE OF CAPILLARY MOVEMENT.

Questions often arise as to how far moisture will be brought up in different soils by capillarity from a body of free water, and at what rate the water will reach points at various heights above the water surface. Table 4 gives some indication of the answers.

TABLE No. 4.—*Rise of capillary moisture in soils for different periods of time and rate of movement of the moisture.*

Distance above water surface.	Light clay loam.		Lava ash soil.		Sandy loam.	
	Time in days.	Acre-inches per day.	Time in days.	Acre-inches per day.	Time in days.	Acre-inches per day.
12 inches	$\frac{1}{13}$	0.193	$\frac{1}{2}$	0.193	$\frac{3}{8}$	0.151
24 inches	$6\frac{1}{2}$	.0035	2	.116	37	.0001
36 inches	55	.0018	$6\frac{1}{2}$	.035	....	None.
48 inches	219	.0001	17	.009	....	....
60 inches	....	None.	50	.005	....	....
72 inches	....	....	200	.0001	....	....

The table but emphasizes the fact that the finer the soil texture the greater its capillary power, and it also shows the fallacy of attempting to keep the subgrade dry by shallow drainage or the building of low fills over soil saturated with water or where the underground water table is nearer than 5 or 6 feet to the surface,

unless the soil be sandy. The table shows that in lava ash soil of the type used in the experiment there will be brought to the surface through 5 feet of soil 1.8 acre-inches of water in a year, and through 4 feet of this soil there would be brought to the surface in the same time 3.3 acre-inches. Five and one-half inches of water would be brought up through 1 foot of sand, but through 2 feet of sand only one-half acre-inch of water would be brought up in a year.

It is difficult to estimate the amount of the evaporation of moisture from below the midpoint of a paved highway. Near the outer edge of the pavement the rate of evaporation may be very rapid, but in the center the moisture would first have to move horizontally to a crack or through 8 or 10 feet of soil to the outer edge of the pavement. On the deserts of the West the rate of evaporation from a wet soil may be one-half inch per day, and under some conditions even more. The rapid evaporation of the moisture near the outer edge of the pavement might, and sometimes does, result in a dry subgrade at and near the outer edge of the pavement and a wet subgrade in the center. In the heavier soils this would result in a subgrade of unequal supporting power and, through contraction and expansion resulting from unequal moisture content, leave an unsupported outer edge of the pavement or a mushy yielding subgrade center. According to Prof. William H. Burr, M. Am. Soc. C. E., the safe-bearing power of dry clay is 4 to 6 tons per square foot; that of moderately dry clay 2 to 4 tons; and that of soft, moist clay 1 to 2 tons. Hool and Johnson give as the safe-bearing power of quicksand ½ to 1 ton per square foot, gravel and coarse sand well cemented 8 to 10 tons, and clean dry sand 2 to 4 tons. These figures indicate the effect of moisture in the subgrade in its relation to load-bearing strength.

CAPILLARY SYPHON MAY CAUSE WATER-LOGGING.

Where a highway is built through a country having a transverse slope of 15 degrees or more the movement of moisture down this slope by capillarity is relatively very rapid and extensive. If a sand or gravel stratum is present (especially if it be on top of a clay or other impervious or semi-impervious layer) then the capillary movement of moisture is much more rapid and will extend for great distances. Such soil conditions are not at all uncommon in an alluvial country and afford ideal conditions for the capillary syphoning of water.

The capillary movement of soil moisture from a free water surface is very rapid for the first 48 hours, and for that reason, shallow side drain ditches are not effective in preventing the capillary movement of moisture into subgrades, especially if these ditches are at all near the pavement. Deep drains are not effective against capillary moisture unless placed below the limit of capillary rise of moisture in the soil under consideration.

That capillary moisture has caused soggy, wet subgrades is beyond question and unless effective preventive measures are taken it will continue to cause highway troubles. Just what these protective measures should be and remain within reasonable cost limits has not yet been ascertained.

The data outlined above were obtained from experiments conducted on the capillary movement of soil moisture where the source of the moisture was free water. The capillary movement of soil moisture from a wet soil to a soil containing a smaller percentage of water differs from what has been shown only in quantity. However, the rate and extent of movement of the moisture under the last named condition is relatively so little as to be almost negligible in highway pavements.

SCHOLARSHIP ESSAY CONTEST ANNOUNCED.

A national essay contest, open to all pupils of high-school grade, with a 4-years' scholarship in any college or university as the prize for the successful contestant, was announced recently by the Highway and Highway Transport Education Committee. The subject prescribed by the committee is "Good Roads and Highway Transport." At the request of the committee Mr. H. S. Firestone, of Akron, Ohio, has consented to furnish the scholarship, which is valued at about $5,000. This is a repetition of Mr. Firestone's offer of last year, which resulted in the awarding of a scholarship to Miss Katharine F. Butterfield, of Weiser, Idaho.

United States Commissioner of Education Dr. P. P. Claxton has requested the superintendents of education of the various States to name State committees to pass upon the essays that are written in each of the States, and the best essay from each State will be sent to Washington, where the national prize winner will be decided by a committee to be appointed by the Commissioner of Education.

The essays must not exceed 500 words in length and must be in the hands of the local committees not later than June 15, or the date of the closing of school in each locality.

Members of the Highway and Highway Transport Education Committee are: Dr. P. P. Claxton, United States Commissioner of Education, chairman; Thomas H. MacDonald, Chief Bureau of Public Roads; Col. Mason M. Patrick, Corps of Engineers, United States Army; Roy D. Chapin, National Automobile Chamber of Commerce; W. S. Keller, president American Association of State Highway Officials; H. S. Firestone, Rubber Association of America; Dean F. L. Bishop, Society for the Promotion of Engineering Education; Dr. Walton C. John, United States Bureau of Education, secretary; and Prof. C. J. Tilden, Yale University, director.

BITUMINOUS PAVEMENTS LAID ON OLD MACADAM STREETS IN DENVER

By J. W. JOHNSON, Senior Highway Engineer, Bureau of Public Roads.

REMOVING THE EXCESS MATERIAL AFTER SCARIFYING THE OLD MACADAM.

THE city and county of Denver, during the past 10 years, have paved a number of streets with various types of bituminous surfaces on old macadam bases. The different types laid to date are asphaltic concrete, tar concrete, "Amiesite," sheet asphalt, and "Willite." The first attempt at this construction was made by the city in 1910, when four blocks on Speer Boulevard were paved. Three types of pavement were laid in the following order, each type being used throughout one block: Asphalt concrete, tar concrete, "Amiesite," and tar concrete. In 1912 the paving on this street was continued for a distance of eight blocks, using asphalt concrete. In the same year a block on Eighteenth Avenue, from Sherman to Grant, was paved with "Amiesite." In 1913 the block between Sherman and Lincoln on Eighteenth Avenue was paved with asphalt concrete.

In 1916, 1917, and 1918, 35 to 40 blocks were paved with sheet asphalt and asphalt concrete. One block of "Willite" was laid in 1919. In 1920 a total of 112,920 square yards of asphalt concrete and "Willite" pavement was laid.

All of the streets paved in this manner had previously been improved by grading, curbing, and gutter and surfacing. The surfacing originally placed varied in different parts of the city. Disintegrated granite, slag, and oil macadam were used.

The width of the streets varied from 30 to 40 feet between curbs. The width of the gutter was usually 2 feet. The crown varied from 8 to 12 inches. All of the streets had previously been supplied with storm sewers. Intakes to sewers were provided at intervals so that the maximum length of run-off of surface water was about 600 feet.

Owing to the light annual precipitation (an average of about 14 inches), the high crown on pavements, and the short distances that surface water has to travel before entering sewers, there is very little opportunity for the subgrade to become wet so long as the pavement is in good condition. Only a very few places where settlement of the subgrade has occurred are in evidence. Practically all of these defects occur under the earlier pavements.

With the exception of a small amount of "Willite," all of the 1920 construction was asphaltic concrete, $1\frac{1}{2}$ inches thick on a $1\frac{1}{2}$-inch binder course. Both Mexican and California asphalt, with a penetration of from 50 to 60, were used. The binder course was mixed in the proportion of 50 pounds of asphaltic cement to 250 pounds of sand and 750 pounds of smelter slag (maximum size 1 inch). The surface course was mixed in the proportion of 80 pounds of asphaltic cement to 85 pounds of limestone dust, 300 pounds of slag (maximum size $\frac{5}{8}$ inch), and 535 pounds of sand.

The mixing was done at stationary plants and the material was transported to the job in auto trucks. The mixing plants and trucks are owned and operated by the city. All of the work, including the grading and preparation of the subgrade, is done by the city by day labor. No contracts are let for any portion of the work of this character.

PREPARATION OF SUBGRADE.

The surface of the street selected for paving is scarified by the use of a scarifier attached to a heavy blade machine and pulled by a 10-ton caterpillar tractor. The depth and amount of scarifying depends on the condition of the old macadam and the amount necessary to be removed. As all of the streets paved

have either brick or concrete gutters, it becomes necessary to remove 3 inches of old material at the junction of pavement and gutter. From this point the amount of material removed is decreased to the center of the road, where only the amount necessary to bring the road to a uniform crown is taken off.

The material loosened by the scarifier is bladed into windrows, about 6 feet wide and 3 feet high, and then loaded into wagons by means of a traveling bucket loader. After the excess material is removed the roadbed is thoroughly rolled until hard and firm. All depressions are then filled with good material and again rolled and brought to a uniform grade and cross section.

Upon this subgrade the asphalt binder course and surface course are laid in accordance with usual practice in laying asphalt pavement.

COST OF PAVEMENT.

The number of square yards of pavement of this character laid during the season of 1920 was 112,920. The total cost of this work was $127,768.77, which is at the rate of $1.13 per square yard. This price included the grading necessary to prepare the subgrade.

The average cost of grading amounted to $0.15 per square yard of pavement. In other words, the pavement cost an average of $0.98, and the grading $0.15 per square yard.

The items of cost of the work done in 1920 are as follows:

Item.	Cost per square yard.
Surface mixture	$0.281
Binder mixture	.210
Fuel	.071
Expense	.010
Tools and sundries	.023
Plant repairs	.030
Depreciation plant	.013
General salaries	.040
General labor	.013
Plant labor	.115
Street labor	.088
Hauling	.086
Total for surfacing	.980
Grading	.150
Total	1.13

The various charges entering into the above items are explained as follows· Surface and binder mixture include the cost of asphalt, limestone dust, sand and slag which are used in them.

Fuel covers all coal used at plant and on steam rollers on job and fuel oil in the dryer and electric power for derrick.

Expense includes insurance, taxes, printing, automobile and miscellaneous expenditures.

Tools and sundries include the purchase of tools and miscellaneous plant supplies, water rental, horse feed and shoeing, lubricating oil and grease.

Plant repairs include repairs and replacements to plant and roller parts; also labor in getting plant in shape before starting up in the spring.

Depreciation is 20 per cent of the cost of new equipment purchased.

General salaries include those of the superintendent, bookkeeper at plant, clerk at administrative office, and an inspector.

General labor includes labor in building addition to plant, assembling derrick and any other work not properly chargeable to operation.

Plant labor includes all labor used in operating the plant.

Street labor includes all labor used on the street in laying the binder and top.

Hauling includes the cost of trucks and drivers, and street rollers and operators.

Grading includes all labor in preparing subgrade.

PRESENT CONDITION OF PAVEMENT.

The most noticeable defects in the present condition of these pavements are sunken spots, roughness or waves in the surface, and surface cracks. The sunken places are all on work done in 1910 and 1912. The largest of these have a diameter of from 8 to 10 feet, and are possibly 8 to 12 inches below grade. This condition is caused by settlement of the subgrade, which was on a comparatively new fill of from 4 to 10 or 12 feet. The street on which these sunken places occur was built along the bank of Cherry Creek, parallel to new retaining walls built to confine the water course of the creek. The surfacing was placed on this fill within two years after it was constructed, and evidently prior to the time of complete settlement.

Roughness and waves are in evidence on a number of streets laid during the early period of this construction. Apparently this condition is caused by insufficient care in laying the pavement, or insufficient rolling of the subgrade. This condition does not exist to any extent in work done since 1916.

Transverse cracks in the pavement laid in 1916, 1917, and 1918 are in evidence throughout a large portion of the work. These cracks are usually at right angles to the center line of roadway. Sometimes they extend entirely across the pavement from gutter to gutter, and sometimes they extend only a distance of 6 or 8 feet each side of the center. Apparently they are caused by contraction and do not indicate any serious permanent defect in the wearing qualities. The distance between them varies considerably; ordinarily they are not less than 30 feet apart.

One block of surfacing laid in 1919 shows the worst cracking of any so far laid. This pavement is so badly cracked that it will undoubtedly have to be replaced in a very short time. In fact it should be replaced this season. This cracking was apparently

LAYING THE SHEET ASPHALT TOPPING.

caused by the pavement being mixed with too small a percentage of asphalt. The resulting mixture was too brittle, and severe cracking was evident after the first cold weather in the fall after the pavement was laid.

One disadvantage in this method of constructing pavements is the high crown which very often obtains. This result is caused from the desire to use all of the old macadam possible in the center of the road, and the necessity of meeting the gutter already in place. As the macadam has usually been given a good crown for drainage, the addition of 3 inches of bituminous pavement will as a rule result in 1 or 2 inches of additional crown. This result would be more undesirable in a wet, cold climate than under the climatic conditions usual in Denver.

Acknowledgment is made to Mr. C. H. Draney, superintendent of the paving division of the city and county of Denver, for his courtesy and assistance in supplying information and data relative to this work.

THE PRESIDENT'S MESSAGE ON FEDERAL HIGHWAY POLICIES.

President Harding's first message to Congress, delivered April 12, contains the following statement with regard to Federal participation in highway construction:

Transportation over the highways is little less important [than railway transportation], but the problems relate to construction and development, and deserve your most earnest attention, because we are laying a foundation for a long time to come, and the creation is very difficult to visualize in its great possibilities.

The highways are not only feeders to the railroads and afford relief from local burdens, they are actually lines of motor traffic in interstate commerce. They are the smaller arteries of the larger portion of our commerce, and the motor car has become an indispensable instrument in our political, social, and industrial life.

There is begun a new era in highway construction, the outlay for which runs far into hundreds of millions of dollars. Bond issues by road districts, counties, and States mount to enormous figures, and the country is facing such an outlay that it is vital that every effort shall be directed against wasted effort and unjustifiable expenditure.

The Federal Government can place no inhibition on the expenditure in the several States, but since Congress has embarked upon a policy of assisting the States in highway improvement, wisely, I believe, it can assert a wholly becoming influence in shaping policy.

With the principle of Federal participation acceptably established, probably never to be abandoned, it is important to exert Federal influence in developing comprehensive plans looking to the promotion of commerce, and apply our expenditures in the surest way to guarantee a public return for money expended.

Large Federal outlay demands a Federal voice in the program of expenditure. Congress can not justify a mere gift from the Federal purse to the several States, to be prorated among counties for road betterment. Such a course will invite abuses which it were better to guard against in the beginning.

The laws governing Federal aid should be amended and strengthened. The Federal agency of administration should be elevated to the importance and vested with authority comparable to the work before it. And Congress ought to prescribe conditions to Federal appropriations which will necessitate a consistent program of uniformity which will justify the Federal outlay.

I know of nothing more shocking than the millions of public funds wasted in improved highways; wasted because there is no policy of maintenance. The neglect is not universal, but it is very near it. There is nothing the Congress can do more effectively to end this shocking waste than condition all Federal aid on provisions for maintenance. Highways, no matter how generous the outlay for construction, can not be maintained without patrol and constant repairs. Such conditions insisted upon in the grant of Federal aid will safeguard the public which pays and guard the Federal Government against political abuses, which tend to defeat the very purposes for which we authorize Federal expenditure.

SAND AND GRAVEL PRODUCTION SURVEY OF TWENTY-TWO STATES.

By GEORGE E. LADD, Economic Geologist, Bureau of Public Roads.

IN spite of the fact that the United States has under way a vast road-building program, except in very few States no systematic survey of road materials has been undertaken. The United States Bureau of Public Roads has records of thousands of tests of road materials, and State highway organizations have similar records, for their own territories, respectively, but field information is lacking. Testing records are worthless in themselves unless it is known that the sample collected represents an average of a workable deposit. The information needed is much broader in scope. The highway engineer must know where material is available, the nature of the occurrence, extent, thickness, accessibility, transportation facilities, conditions affecting production—in short availability for roads, and the necessary costs involved in getting the materials, in desired form and condition, to the roads.

The Dominion of Canada has long conducted systematic surveys of its road materials. A few of our own States are compiling and publishing information on this subject, but very little indeed has been done in the way of systematic surveys undertaken and conducted with the needs of the highway engineer in mind. The Bureau of Public Roads has carried on economic studies of rock excavation and the production of broken stone. It has compiled lists of broken stone, and sand and gravel producers in the United States, and has assembled all available information on the occurrence of road materials from publications and records of geological surveys, university geological departments, mining bureaus and State highway commissions.

SURVEY OF 536 PLANTS.

During the field season of 1920, because of problems arising in the administration of the Federal aid road act, a survey of producing sand and gravel plants in the United States was begun and work was completed in 22 States. During the progress of this work, as much general information as possible was obtained, collaterally, about the distribution and quality of sand and gravel deposits in the area covered; and so far as possible our list of broken stone producers was revised. A detailed study was made of the sand and gravel industry as a source of road materials. Approximately 1,000 pits and plants were visited in the area under consideration.

The tabulated information which follows pertains to 536 plants, at which 13 different methods of excavation were noted.

These tables do not include data on molding, glass or other special sands, crushed sandstone, or hand excavating plants at sand and gravel pits, unless the latter have a capacity of at least 300 tons per day. It should be borne in mind, therefore, that table No. 2, totals the production figures only of the plants under consideration in this paper. Many States possess widespread gravel deposits of excellent quality which occur so generally, and from which material is so readily obtained for local use, that permanent-type plants are few in number or entirely absent. This is noticeable especially in the New England States, where the scarcity of sand and gravel plants of the types included in the tables below is not the result of the absence of sand and gravel deposits, but, on the contrary, because they may be found wherever need occurs.

Lest the terms "wet" and "dry" as used in the following tables be misunderstood, the reader's attention is called to the fact that these terms are used in reference to excavating conditions only, and not to screening methods. As a matter of fact very few plants listed are dry plants in the latter sense.

When the survey was started car shortage was acute, and information on that subject was gathered. Although there has been a complete reversal of that condition within the past few months, results of car shortage as they affected this industry are indicated in Table No. 2.

Information obtained by field men on this survey was embraced in a questionnaire and instructions which covered the following points: Name and address of the operator; location of plant; transportation facilities; geological occurrence of the deposit; amount of stripping; thickness of deposit where obtainable; thickness worked; kind and character of material; notes on percentage of sizes; variations throughout the bed; mechanical analysis of the commercial product; uses of the products; sand and gravel production for 1919 and 1920; tonnage sold for road purposes; daily capacity of plants; length of operating season; effect of car shortage on production; sketch of plant arrangement; description of plant and method of operation, with flow sheet; kind and amount of power used; details of screening operation; storage arrangements; labor employed at each unit of operation.

Many photographs were taken and samples of sand products were collected and sent to the bureau laboratory for mechanical analysis and microscopic examination.

FEW COMMERCIAL PLANTS IN NEW ENGLAND.

In the New England States, Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island, glacial gravel and sand beds are widespread. They are mostly worked in original deposits, bu

stream gravels are used, particularly in Vermont, where so many roads are built in the narrow valleys of the Green Mountains.

Clamshell dredges operate from Boston for sea sand, and dredging boats sometimes operate from points in Maine. For a generation past great quantities of sharply angular quartz sand have been taken from the harbor at Newburyport, Mass., at the mouth of the Merrimac River. Throughout New England local pits are worked for road material as needed, and all the cities and towns of consequence have sand and gravel beds within or near them, from which material is hand excavated and used as "bank run," or as dry screened sand and gravel. The total output from such pits is large.

In Maine and New Hampshire, mechanical-power excavation is confined to steam shovels. In Massachusetts and Connecticut steam shovels, derricks, locomotive crane clamshells, and centrifugal pumping are the methods used for excavating. At West Peabody, Mass., there is a pumping plant which is unique in that it delivers its product to the screens by two stages; a centrifugal pump on a boat in a pond delivers the material by a 12-inch pipe line to a hopper on shore, whence it is boosted by another centrifugal pump up a 400-foot incline to the top of the screening plant 100 feet above.

The States of Vermont and Rhode Island use local-type pits only.

THE MIDDLE ATLANTIC STATES.

In New York State, most of the plants produce their sand and gravel from banks of glacial origin, but dredges are operated in Long Island Sound and in the Niagara River. The land plants in this State excavate with steam shovels, mechanical diggers, derricks, and locomotive crane clamshells and cableway draglines. The Niagara River dredges, operating near Buffalo, are centrifugal-pump boats and one ladder dredge, with gravity screens which separate the sand and gravel. The product is brought to yards at Buffalo, where it is unloaded by clamshell cranes. The Long Island Sound plants use clamshell dredges, and the material is towed to screening and washing plants on shore.

Land plants in New Jersey operate in banks sand and gravel by means of steam shovels, mechanical diggers, derricks, locomotive crane clamshells and cableway draglines, and by pump boats with pipe lines which discharge to gravity or cylindrical screening plants. Operations in the Delaware River are confined to ladder dredges, which work between Philadelphia and Trenton.

There are many gravel banks in New Jersey which are operated by hand, and in which the material is loaded directly from the bank to wagons, trucks, and railroad cars.

In Pennsylvania, most of the sand and gravel plants occur in the glacial deposits of the northern part of the State. A few land plants occur elsewhere, in old river terraces. Much sand and gravel is also taken from the Delaware, Allegheny, Monongahela, Ohio and Susquehanna Rivers. In this State, four hand-operated plants have a sufficiently large production to justify their inclusion in the tables which follow. Of the plants which operate by strictly dry excavation methods the majority use steam shovels. One locomotive-crane clamshell is in operation and three cableway draglines. Two plants use cableway draglines for excavating from small streams. The 20 plants obtaining their material from the larger rivers are evenly divided between pumping boats and ladder dredges. In the Pittsburgh district, ladder dredges are used exclusively for river work. Revolving cylindrical screens are used on the dredges and the products delivered to barges alongside, the latter being towed to yards along the river bank.

In the Williamsport district, centrifugal pump boats are used exclusively, all material being otherwise handled as in the Pittsburgh district, except that a few use gravity screens only. In the Philadelphia district, both ladder and clamshell dredges are used for river work. Material is screened on the dredges and delivered by barges to storage yards in Philadelphia and other points. There are no pipeline, pump-boat plants operating in Pennsylvania.

The States of Delaware, Maryland, and the District of Columbia may be considered together. In this area, the sand and gravel is obtained locally, mostly from old river terraces and small streams. The Delaware plant operates on a large scale, excavating with derrick clamshell, in sand dunes, originating from beaches on the Delaware Bay. In Chesapeake Bay and the Potomac River, ladder dredges are used. The material is usually washed and screened on the boat, and the product delivered to barges. Excess sand is discharged from the side of the boat. Unloading on shore is done with the use of derrick clamshells. Some dredges, however, deliver by barge to washing and screening plants on shore. Among the inland deposits of sand and gravel, other than the sand dunes referred to above, sand and gravel deposits, varying in thickness from 12 feet to 30 feet, are worked by steam shovels and derrick clamshells.

Some gravel and an abundance of sand, of excellent grade, occur in the Cretaceous, Tertiary, and Quaternary formations on the eastern shore, and in the Palæozoic formation of western Maryland. Sand also occurs in the tidal streams and estuaries, from which it it extensively dredged. A short account of sand and gravel in this State may be found in the Maryland Geological and Economic Survey, Report of 1908, Part II, Volume VIII.

VIRGINIA AND WEST VIRGINIA.

In Virginia, there are 14 sand and gravel producers of the class under discussion in this article. Sand and gravel deposits may be found along many streams and in river terraces. Land deposits are mostly worked by dragline excavators—two plants use cableway draglines and two plants use steam shovels. River and bay work is conducted by pumping plants or ladder dredges. These are found on Little River, 12 miles northeast of Richmond, and on the James River and Chesapeake Bay. A Baltimore corporation, which operates from Norfolk, Va., on the James River, and at Petersburg, Va., is reported as using ladder type dredges in addition to pump boats. Land deposits are relatively thin. None of those at present being worked exceed 25 feet in thickness. Operation in these deposits is therefore relatively expensive. Plants operate the year round in this State.

In West Virginia, sand and gravel deposits are comparatively scarce. Exclusive of small hand-operated pits only six land deposits are worked. Operations at these are conducted by derrick clamshells, cableway draglines, steam shovels, and horse scrapers. River deposits are worked by 14 producers, the operations of which are equally divided between centrifugal pumps and ladder dredges. Land plants use gravity screens only. Ninety-five per cent of the sand [1] produced in West Virginia is dredged from the Ohio and Elk Rivers or pumped from smaller streams. The ladder dredges on the Ohio and Elk Rivers are equipped with screening plants, whence material is towed to shore in barges. It is then delivered to storage piles or hoppers for truck and railroad car, loading by clamshells. A few plants further subdivide their material by shore screening. The stream pumping plants in West Virginia operate with 6 and 10 inch centrifugal pumps, some of which discharge to barges, and others, by pipe lines, to gravity screens on shore.

OHIO AND INDIANA HAVE MANY LARGE PLANTS.

In Ohio, sand and gravel beds are widely distributed and, over much of the State, are of glacial origin. Forty-five land plants are included in the list of this survey. Twenty-seven of these are operated by steam shovels. There are no mechanical diggers or dragline scrapers in operation in the State.

All other methods of excavation, however, are used, there being a greater variety of methods of operation found in Ohio than in any other State studied. Large, modern-type plants are common.

Pumping and dredging plants operate in Lake Erie, the Ohio River, and in some of the smaller rivers of the State. The three types of dredges (ladder, dipper, and clamshell) are found in this State. Eighteen plants excavate by centrifugal pumps. Some screening is done immediately on the dredges, but some pump boats deliver by pipe lines to screening plants on shore. On Lake Erie, the method of operation is pumping, the material being delivered to barges.

The State of Indiana is remarkably well supplied with sand and gravel, and commercial, permanent-type plants are found in all parts of the State with the exception of a portion of its southern extremity, which was unglaciated, and a few counties in the northwestern part of the State. Southern Indiana is well served with these road materials through deposits taken from the Ohio and Wabash Rivers. For local use in the southern part of the State there are widespread deposits of stream gravels mixed with iron carbonate nodules, which are residual from the decomposition of shale and clay strata. Stream gravels occur generally over the State, and consist mostly of reassorted materials from glacial drift. The sand and gravel land plants in this State number 52. The majority of these excavate with cableway draglines and steam shovels; a few use the dragline excavators; and a few others derrick and locomotive-crane clamshells. Excavation from the Wabash and Ohio Rivers is accomplished almost entirely by centrifugal pumps. No ladder dredges are used, and only one clamshell dredge. Hydraulic stripping was noted at a number of plants in Indiana. The operating season varies from 7 to 10 months. In 1905 the Geological Survey of Indiana published an exhaustive report on the occurrence and distribution of road materials in the State.

In Illinois, gravel deposits are scarce in the central, eastern, and southern portions of the State, and these districts are served through plants on the Mississippi River, at the mouth of the Ohio River, and on the Wabash River. This statement, while true in general, applies specifically to deposits suitable for commercial development on a large scale. There are 55 permanent-type sand and gravel plants in Illinois. Of these, 32 are land plants, 5 of which operate by dragline method below water level. Sixteen of this class of plants excavate by steam shovels; two use mechanical diggers, while others use dragline cableways, excavators, and scrapers, and both derrick and locomotive crane clamshells.

The State highway department of this State has published, in its Bulletin No. 14, a report on "Materials Available for Highway Construction in Illinois." The Illinois Sand and Gravel Producers Association has a comprehensive report on the sands and gravels of the State, which is known as "General Letter No. 24."

MICHIGAN'S GLACIAL GRAVELS INEXHAUSTIBLE.

Michigan, like New England, has an apparently inexhaustible supply of glacial gravels, occurring in the form of ridges, known as "hog-backs" and eskers, in irregular hills called "kames" and in outwash plains and deltas. There are enormous deposits of gravels

[1] Consideration of crushed sandstone plants, which are numerous in both West Virginia and Pennsylvania, is omitted in this paper.

also in the old beach ridges in Presque Isle and Alpena Counties, bordering on Lake Huron. The latter gravels, however, are chiefly of limestone and of low grade. Sand and gravel plants occur wherever there is demand for material. Most of them are in the southern half of the State. There are 57 plants in Michigan, two of which use more than one method of excavation; 50 of these are dry land plants. The steam shovel and cableway dragline methods of excavation prevail. One plant uses a dragline scraper; six, dragline excavators; seven, locomotive-crane clamshells; and three, derrick clamshells. In this State, many of the plants using cableway dragline excavators deliver to a stock pile over a tunnel which feeds to conveyer belts leading to screens. Of the seven distinctly wet-class plants in Michigan, one should perhaps be included in the class of land plants, as its operations are in a glacial deposit, and the sand and gravel is pumped through a 15-inch pipe line from an artificial lake. This plant is operated as is one, described above, in Massachusetts. At the Michigan plant material is picked up in the lake by a centrifugal pump, which is driven by a 400-horsepower electric motor. It is then conducted 300 feet through a 15-inch pipe line laid on pontoons. A booster pump on shore delivers the material up a 200-foot incline of 20° to screens.

In the St. Clair, Detroit, and St. Joe Rivers and Lakes St. Clair and Erie, operators excavate sand and gravel by means of clamshell dredges and centrifugal pumps. In this State, the stripping is comparatively thin and at most plants the overburden is carried to the plants, and eliminated by washing. The operating season varies from 75 to 250 days per year.

An account of the road materials of Michigan may be found in publication No. 27, Geological Series No. 22, of the Michigan Geological and Biological Survey for 1917 and prior years.

WISCONSIN WELL SUPPLIED.

Few States have a greater abundance of road material than has Wisconsin. Suitable materials are found in nearly every county. The southwestern quarter of the State is free from "drift." Elsewhere glacial sand and gravels are common. A great majority of the producing plants are located in the southeastern quarter. Thirty-one permanent-type sand and gravel producers operate in this State. One of these, only, produces from Lake Superior. This company excavates with clamshell dredges and occasionally takes gravel from beaches, bringing the material within reach of the clamshell by means of dragline scrapers. One plant operates a centrifugal pump boat in an artificial lake. At this plant the material is delivered through a 10-inch pipe line to a settling pit, whence it is loaded direct to cars, without screening, by clamshell. Eleven land plants excavate with steam shovels and eight with cableway draglines. Derrick clamshells, dragline excavators, and scrapers are also used. In Wisconsin mechanical diggers are more extensively used than in any other State. The latter may be seen to good advantage at Janesville, where they are operated by electric power and deliver to conveyor belts from high banks of loose material—favorable conditions for these machines.

The Wisconsin deposits are especially free from clay, but in the Janesville district the overburden reaches a thickness of 6 feet. In other districts the amount of stripping is small.

Local pits supply road material in many parts of the State. A number of counties in Wisconsin own and operate sand and gravel plants.

The Wisconsin Geological and Natural History Survey has published a report on the natural road materials of Wisconsin. There is little reference to sand and gravel although the distribution of glacial drift is discussed and outlined by map.

Glacial drift covering Minnesota provides sand and gravel as needed. Most of the large producing plants are in the southeastern quarter of the State, and, naturally, many of these are grouped about the large centers of population at St. Paul and Minneapolis. A large number of plants in this State excavate with steam shovels and dragline cableways; others use mechanical diggers, derrick clamshells, dragline excavators and scrapers. Five plants excavate with centrifugal pumps. One company operates on the Mississippi River and another on the Minnesota River. The other three excavate from ponds located in glacial beds of sand and gravel. On Lake Superior, one company operates by pulling the material from beaches by means of steel scrapers. It is then picked up by clamshell dredges and transferred to barges. One company in the State uses bull jigs to separate shale from the gravel.

South Dakota commercial plants are but three in number, and are located near the eastern edge of the State. Data for our tables was therefore gathered by side trips from Minnesota. Methods of excavation were found to be cableway dragline, dragline excavator and steam shovel. Conditions in the rest of the State were not investigated.

IOWA IS COVERED WITH GLACIAL DRIFT.

Iowa is covered with glacial drift except for a small area in the northeastern part of the State, bordering the Mississippi River; consequently sand and gravels abound and are found, suitable for road work, in three-quarters of the counties of the State. In some counties the quantity is insufficient for more than the main roads, and the principal supply must be obtained from the larger streams or from terraces. River terrace gravels are of most importance along the streams flowing from the Wisconsin drift area in the north-central part of the State. Important pits in these terrace

gravels are at Mason City, Iowa Falls, Gifford, Belmond, Clemons, Des Moines, Grand Junction, Lake View, Spencer, Cherokee, Emmettsburg, and Estherville. Gravel hillocks and knobs, known as kames, are abundant in north-central Iowa. Several counties contain gravel plains of under-stream and outwash origin. The kame gravels contain considerable clay, and washing is necessary.

Among the land plants it is worthy of note that 12 cableway draglines are found and but 4 steam shovels. Two plants excavating by means of horse scrapers are included in our statistical tables because of the amount of their production. Four companies operate dragline scrapers; three, locomotive-crane clamshells, and one, derrick clamshell. The sand and gravel industry in Iowa is exceptional in that a large majority of the plants excavate by means of pumps. Forty-three companies use this method. There are a few large pumping plants which operate in artificial ponds in sand and gravel deposits. The majority of them, however, take their material from the Mississippi and Des Moines Rivers and some of the smaller streams.

The Iowa Geological Survey in volume 24, Annual Report, published a comprehensive account of the road materials of the State.

Kentucky, as compared with the States over which glacial drift is deposited, is greatly lacking in sand and gravel deposits. The Ohio River, however, is a source of supply for shipping purposes, and nearly all of the permanent-type plants of the State are located along this river. Many pits for local use occur in stream deposits over the State. Some of the deposits worked near Louisville and Ludlow may be of glacial origin, as a point of glacial drift penetrates a short distance into the State at this point. Some material is taken from the bed of the Kentucky River by pump dredges, and some from the old terraces along this stream. Tennessee River terraces furnish an abundance of coarse gravel as well as sand. Such a deposit has been worked up to a thickness of 50 feet, the total thickness being undetermined. Three companies in Kentucky excavate with steam shovels; one, with dragline excavator; seven, with centrifugal pumps; and one, with clamshell dredge. The river pumping plants clean and size the material on dredge boats, whence it is delivered by chute to barges, and finally unloaded on shore by clamshell or cableway dragline. The river pumping plants in this State operate about eight months in the year, while land plants occasionally operate throughout the year.

TABLE 1.—Permanent-type commercial sand and gravel plants.[1]

MAINE.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Bangor Cast Stone Co	Bangor, Me	East Hampden, Me	Dry; steam shovel.
Maine Crushed Rock & Gravel Co	Portland, Me	Leeds, Me	Do.

NEW HAMPSHIRE.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Standard Sand & Gravel Co	Portland, Me	Milton, N. H	Dry; steam shovel.

MASSACHUSETTS.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Bernie Sand & Gravel Co	Wilbraham, Mass	Wilbraham, Mass	Dry; steam shovel.
Boston Sand & Gravel Co	Boston, Mass	Scituate, Mass	Do.
Do	do	Greenbush, Mass	Do.
Connolly Co	do	Topsfield, Mass	Do.
Highland Sand & Gravel Co	West Roxbury, Mass	West Roxbury, Mass	Do.
John C. Kelly & Co	do	do	Dry; locomotive crane clamshell.
Massachusetts Sand & Gravel Co	Newton Upper Falls, Mass	Newton Upper Falls, Mass	Dry; derrick clamshell.
J. H. McNamara	Boston, Mass	Wellesley, Mass	Dry; locomotive crane clamshell.
Do	do	Watertown, Mass	Do.
New England Sand & Gravel Co	do	West Peabody, Mass	Wet; pump.
Do	do	Walpole Heights, Mass	Dry; dragline excavator.
George H. Noone Sand & Gravel Co	West Roxbury, Mass	West Roxbury, Mass	Dry; locomotive crane clamshell.

CONNECTICUT.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Atlas Sand & Gravel Co	Hartford, Conn	Farmington, Conn	Dry; steam shovel.
Edward Balf Co	do	Connecticut River	Wet; clamshell dredge.
Bridgeport Sand & Gravel Co	Bridgeport, Conn	Bridgeport, Conn	Dry; derrick clamshell.
F. W. Fuller	Torrington, Conn	Torrington, Conn	Dry; dragline excavator.
Iron Ledge Co	Bridgeport, Conn	Turnbull, Conn	Wet; dragline excavator.
New London Sand & Stone Co	New London, Conn	Massapeag, Conn	Dry; dragline excavator.
W. & W. Sand & Gravel Co	Ansonia, Conn	Seymour, Conn	Dry; locomotive crane clamshell.

[1] A few plants are included which, although not having a permanent type of plant, produce 300 tons or more daily.

TABLE 1.—Permanent-type commercial sand and gravel plants—Continued.

NEW YORK.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Allegheny Sand & Gravel Co	Olean, N. Y	Allegany, N. Y	Dry; steam shovel.
Apex Sand & Grit Co	Buffalo, N. Y	Williamsville, N. Y	Do.
Buffalo Gravel Corporation	do	Buffalo, N. Y	Wet; pump and ladder dredge.
J. E. Carroll Sand Co	do	Attica, N. Y	Dry; locomotive crane clamshell.
Darwin Springs Sand & Gravel Co	Syracuse, N. Y	Darwin Springs, N. Y	Dry; derrick clamshell.
George F. Dulin	Mechanicsville, N. Y	Willow Grove, N. Y	Dry; locomotive crane clamshell.
Fredrisks' Sand & Gravel Co	Fishers, N. Y	Fishers, N. Y	Dry; steam shovel.
Goodwin-Gallagher Sand & Gravel Co	New York City	New York City	Do.
Kieth O. Guthrie	Schenectady, N. Y	Yosts, N. Y	Wet; pump.
Hill Sand & Gravel Co	Fishers, N. Y	Fishers, N. Y	Dry; derrick clamshell.
Holloway Sand Co	Buffalo, N. Y	Buffalo, N. Y	Wet; pump.
Machias Sand & Gravel Co	do	Machias, N. Y	Dry; cableway dragline.
Marlboro Sand & Gravel Co	New York City	Marlboro, N. Y	Dry; steam shovel.
Nassau Sand & Gravel Co	do	Roslyn, Long Island	Do.
Niagara Sand Corporation	Buffalo, N. Y	Buffalo, N. Y	Wet; pump.
Oak Corners Sand Co	Geneva, N. Y	Oak Corners, N. Y	Dry; mechanical digger.
Perry-Bealzel Sand Co	Rochester, N. Y	Pittsford, N. Y	Dry; derrick clamshell.
Fred Pierce Sand Co	Fulton, N. Y	Arrowhead, N. Y	Dry; steam shovel.
Scottsville Sand Co	Scottsville, N. Y	Scottsville, N. Y	Do.
Henry Steers Sand & Gravel Co	New York City	Northport, N. Y	Wet; clamshell dredge.

NEW JERSEY.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Absecon Sand Co	Absecon, N. J	Absecon, N. J	
Albion Sand Co	Yardville, N. J	Yardville, N. J	Dry; derrick clamshell.
Bennett Gravel Co	Spring Lake, N. J	Allenwood, N. J	Dry; steam shovel.
Do	do	Farmingdale, N. J	Do.
Cape May Sand Co	Cape May, N. J	Cape May, N. J	Do.
C. W. Crane & Co	New York City	South Amboy, N. J	Do.
Delaware River Sand & Dredging Co	Bordentown, N. J	Bordentown, N. J	Wet; ladder dredge.
S. W. Downer	Downer, N. J	Downer, N. J	Dry; steam shovel.
Daniel Goff & Co	Philadelphia, Pa	Millville, N. J	Do.
Hainesport Mining & Transportation Co	do	Bridgeboro, N. J	Do.
Do	do	do	Wet; ladder dredge.
John G. Hodgson	Stanhope, N. J	Near Netcong, N. J	Dry; derrick clamshell.
Lakewood Sand Co	South Lakewood, N. J	South Lakewood, N. J	Dry; mechanical digger.
Menantico Sand & Gravel Co	Millville, N. J	Menantico, N. J	Wet; pump.
William C. Moore	Tuckahoe, N. J	Tuckahoe, N. J	Dry; steam shovel.
Morris County Crushed Stone Co	Morristown, N. J	Morristown, N. J	Do.
New Jersey Sand & Gravel Co	Yardville, N. J	Yardville, N. J	Dry; derrick clamshell.
Norcross & Edmunds	Philadelphia, Pa	Birmingham, N. J	Dry; steam shovel.
Do	do	South Pemberton, N. J	Wet; locomotive crane clamshell.
Ridner Bros	Succasunna, N. J	Succasunna, N. J	Wet; pump.
Seguine & Bogart	Kenvil, N. J	do	Do.
Do	do	Kenvil, N. J	Do.
J. M. Stokes	Rancocas, N. J	Rancocas, N. J	Dry; steam shovel.
Succasunna Sand Co	Morristown, N. J	Succasunna, N. J	Wet; pump.
Warren Sand & Gravel Co	Easton, Pa	Carpentersville, N. J	Dry; cableway dragline.

PENNSYLVANIA.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Beaver Sand Co	Beaver, Pa	Beaver, Pa	Dry; cableway dragline.
Crawford Sand & Gravel Co	Meadville, Pa	Meadville, Pa	Dry; locomotive crane clamshell.
Curtis Hill Sand & Gravel Co	Morrisville, Pa	Morrisville, Pa	Dry; steam shovel.
J. K. Davidson & Bros	Pittsburgh, Pa	Rivers near Pittsburgh	Wet; ladder dredge.
Erie Sand & Gravel Co	Erie, Pa	Erie, Pa	Wet; pump.
A. R. Gilmore Sand Co	Linden, Pa	Linden, Pa	Do.
Griff Construction Co	Erie, Pa	Erie, Pa	Dry; cableway dragline.
W. W. Gulick Sand Co	Lime Ridge, Pa	Lime Ridge, Pa	Dry; steam shovel.
Hazen Sand Co	Bangor, Pa	Mount Bethel, Pa	Do.
Iron City Sand Co	Pittsburgh, Pa	Rivers near Pittsburgh	Wet; ladder dredge.
Keystone Sand & Supply Co	do	Near Neville Island, Pa	Do.
Kincaid & Wade	Warren, Pa	Warren, Pa	Wet; cableway dragline.
Lake Shore Sand Co	Erie, Pa	North East, Pa	Wet; pump.
Lycoming Silica Sand Co	Fairfield, Pa	Fairfield, Pa	Dry; steam shovel.
McClain Sand Co	Point Marion, Pa	Point Marion, Pa	Wet; pump.
Moosic Sand Co	Moosic, Pa	Moosic, Pa	Dry; hand.
Nickle Plate Gravel Co	Erie, Pa	Fairview, Pa	Dry; steam shovel.
Ohio River Sand Co	Pittsburgh, Pa	Rivers near Pittsburgh	Wet; ladder dredge.
Penn Sand & Gravel Co	Philadelphia, Pa	Wheatsheaf, Pa	Dry; steam shovel.
Pittsburgh Sand & Supply Co	Baden, Pa	Baden, Pa	Wet; ladder dredge.
Point Marion Sand Co	Point Marion, Pa	Point Marion, Pa	Wet; pump.
Rock Point Sand Co	Pittsburgh, Pa	West Elwood Junc., Pa	Wet; ladder dredge.
Rodgers Sand Co	do	Rivers near Pittsburgh	Do.
Sayer Sand & Plaster Co	Waverly, N. Y	Sayer, Pa	Dry; steam shovel.
Seguine & Co	Portland, Pa	Portland, Pa	Do.
H. J. Stannert Sand Co	Northumberland, Pa	Northumberland, Pa	Wet; pump.
Do	do	Lewistown, Pa	Do.
D. N. Thomas Sand & Gravel Co	Williamsport, Pa	Williamsport, Pa	Do.
United Ice & Coal Co	Harrisburg, Pa	Harrisburg, Pa	Do.
Universal Sand Co	New Castle, Pa	New Castle, Pa	Dry; steam shovel.
Valley Sand & Supply Co	Parnassus, Pa	Parnassus, Pa	Wet; ladder dredge.
Van Brunt Sand Co	Philadelphia, Pa	Philadelphia, Pa	Do.
Charles Warner Co	do	do	Wet; ladder and dipper dredge.
Washed Sand & Gravel Co	East Bangor, Pa	Mount Bethel, Pa	Dry; steam shovel.
Waid & Yeager	Meadville, Pa	Meadville, Pa	Dry; hand.
Wayne Concrete & Sand Works	Ariel, Pa	Ariel, Pa	Do.
West Branch Sand Co	Duboistown, Pa	Duboistown, Pa	Wet; pump.
Williamsport Sand & Gravel Co	Williamsport, Pa	Williamsport, Pa	Wet; cableway dragline.
Wyoming Clear Sand & Gravel Co	Wyoming, Pa	Wyoming, Pa	Dry; hand.
Wyoming Sand & Stone Co	Wilkes-Barre, Pa	Wyoanna, Pa	Dry; steam shovel.

TABLE 1.—Permanent-type commercial sand and gravel plants—Continued.

DELAWARE.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Lewes Sand Co	Lewes, Del	Lewes, Del	Dry; derrick clamshell.

MARYLAND AND DISTRICT OF COLUMBIA.

Arundel Corporation	Baltimore, Md	Spring Grove, Md	Wet; ladder dredge.
Builders Supply Co	Cumberland, Md	Cumberland, Md	Dry; steam shovel.
Charleston Sand & Stone Corporation	Elkton, Md	North East, Md	Do.
R. F. Clark Sand Co	Severn, Md	Severn, Md	Dry; derrick clamshell.
Columbia Granite & Dredging Co	Washington, D. C	Potomac River near Washington	Wet; ladder dredge.
E. M. Goode Sand & Gravel Co	Havre de Grace, Md	Charlestown, Md	Dry; steam shovel.
L. E. Smoot	Washington, D. C	River near Washington	Wet; ladder dredge.

VIRGINIA.

Arundel Corporation	Baltimore, Md	Petersburg, Va	Wet; pump.
Do	do	Norfolk, Va	Do.
Atlantic Sand Co	Norfolk, Va	Emmerson, Va	Dry; cableway drag line.
J. V. Bickford	Hampton, Va	Hampton, Va	Wet; pump.
Dixie Sand & Gravel Co	Petersburg, Va	Prince George County, Va	Dry; drag-line excavator.
Highland Park Sand & Gravel Co	Richmond, Va	Richmond, Va	Dry; steam shovel.
James River Sand & Gravel Co	Petersburg, Va	Chesterfield County, Va	Wet and dry; cableway drag line.
J. C. Jones Sand Co	Norfolk, Va	14 miles east of Norfolk, Va	Dry; steam shovel.
Massaponax Sand & Gravel Co	Fredericksburg, Va	Massaponax, Va	Dry; drag-line excavator.
Mercer & Miller (Inc.)	Richmond, Va	Little River, Va	Wet; pump.
Old Dominion Sand & Gravel Co	do	Petersburg, Va	Dry; drag-line excavator.
Petersburg Sand & Gravel Corporation	Petersburg, Va	Across river from Petersburg	Do.
Southern Sand & Gravel Co	Richmond, Va	Massaponax, Va	Do.

WEST VIRGINIA.

Armstrong Sand Co	Wheeling, W. Va	Wheeling, W. Va	Wet; ladder dredge.
Bridgeport Wall Plaster Co	do	Wheeling Island, W. Va	Wet; pump.
Corliss Sand Co	New Martinsville, W. Va	New Martinsville, W. Va	Wet; ladder dredge.
Crystal Sand Co	Moundsville, W. Va	Chestnut Hill, W. Va	Dry; derrick clamshell.
Deckers Creek Stone & Sand Co	Morgantown, W. Va	Sturgison, W. Va	Dry; steam shovel.
Kentucky & Ohio Transportation Co	Carrolton, Ky	Huntington, W. Va	Wet; pump.
Laval Sand Co	Hinton, W. Va	Lavalette, W. Va	Do.
New Martinsville Sand Co	New Martinsville, W. Va	New Martinsville, W. Va	Wet; ladder dredge.
Moundsville Sand Co	Moundsville, W. Va	Moundsville, W. Va	Dry; cableway drag line.
Ohio Valley Sand & Slag Co	do	Chestnut Hill, W. Va	Dry; derrick clamshell.
Parkersburg Builders Material Co	Parkersburg, W. Va	Parkersburg, W. Va	Dry; horse scraper.
Parkersburg Sand Co	do	do	Wet; ladder dredge.
Pfaff & Smith Co	Charleston, W. Va	Charleston, W. Va	Do.
Wells Pit Sand Co	Proctor, W. Va	Wells Pit, W. Va	Dry; derrick clamshell.
Western Rivers Co	Point Pleasant, W. Va	Point Pleasant, W. Va	Wet; pump and dipper dredge.
West Virginia Sand & Gravel Co	Charleston, W. Va	Rivers near Charleston	Wet; ladder dredge.
Wheeling Wall Plaster Co	Wheeling, W. Va	Wheeling, W. Va	Do.
Wilson Sand & Gravel Co	Huntington, W. Va	Fork of Coals, W. Va	Wet; pump.
Do	do	Huntington, W. Va	Do.
Zenith Sand Co	St. Albans, W. Va	Fork of Coals, W. Va	Do.

OHIO.

Acme Coal & Builders Supply Co	Toledo, Ohio	River near Toledo, Ohio	Wet; pump.
Akron Sand & Gravel Co	Akron, Ohio	Akron, Ohio	Dry; steam shovel.
The Barnes Sand & Gravel Co	Piketon, Ohio	Near Wakefield, Ohio	Do.
O. K. Barber Concrete Co	Barberton, Ohio	Barberton, Ohio	Not operating 1920.
C. M. Boltz	Springfield, Ohio	Springfield, Ohio	Dry; horse scraper.
Buckeye Sand & Gravel Co	Cincinnati, Ohio	Hageman, Ohio	Dry; cableway dragline.
Central Gravel & Sand Co	Dayton, Ohio	Dayton, Ohio	Dry; steam shovel and cableway dragline.
M. A. Callahan	Cleveland, Ohio	Willow, Ohio	Wet; pump.
Chillicothe Sand & Gravel Co	Chillicothe, Ohio	Chillicothe, Ohio	Dry; steam shovel.
Cleveland Builders Supply & Brick Co	Cleveland, Ohio	Aurora, Ohio	Wet; pump.
Columbus Sand & Gravel Co	Columbus, Ohio	Columbus, Ohio	Do.
Concrete Materials Co	do	do	Wet and dry; dipper dredge and steam shovel.
Edward A. Davis	Bellair, Ohio	Winding Hill, Ohio	Dry; dragline excavator.
Dayton Sand & Gravel Co	Dayton, Ohio	Dayton, Ohio	Wet; cableway dragline.
G. R. Deming Sand & Gravel Co	Piqua, Ohio	Rossville, Ohio	Dry; hand.
Diamond Sand & Gravel Co	Bedford, Ohio	Garfield Heights, Ohio	Dry; locomotive crane clamshell.
Do Ville Lake Sand & Gravel Co	Toledo, Ohio	Maumee River, Toledo, Ohio	Wet; pump.
East End Sand & Gravel Co	Chillicothe, Ohio	Chillicothe, Ohio	Dry; steam shovel.
East Liverpool Sand Co	East Liverpool, Ohio	East Liverpool, Ohio	Wet; ladder dredge.
Fayette Sand & Gravel Co	Washington Courthouse, Ohio	Washington Courthouse, Ohio	Wet; cableway dragline.
Franklin Bros	Akron, Ohio	Akron, Ohio	Dry; steam shovel.
Garland Block & Sand Co	Youngstown, Ohio	Youngstown, Ohio	Dry; locomotive crane clamshell.
Glacial Sand & Gravel Co	Zanesville, Ohio	Gilbert, Ohio	Do.
Greenville Gravel Co	Greenville, Ohio	Fort Jefferson, Ohio	Dry; steam shovel.
Do	do	Mechanicsburg, Ohio	Do.
T. J. Hall & Co	Cincinnati, Ohio	Cincinnati, Ohio	Wet; pump.
Home Sand Co	Fremont, Ohio	River near Fremont, Ohio	Do.
Homegardner Sand Co	Sandusky, Ohio	Sandusky, Ohio	Do.
The Island Sand & Gravel Co	Columbus, Ohio	Columbus, Ohio	Wet; cableway dragline.
Kelly Island Lime & Transportation Co	Sandusky, Ohio	Sandusky, Ohio	Wet; pump.
Killbuck Sand & Gravel Co	Killbuck, Ohio	Killbuck, Ohio	Dry; steam shovel.
Lake Erie Sand Co	Sandusky, Ohio	Sandusky, Ohio	Wet; pump.
Le Beau Wrecking Co	Toledo, Ohio	River near Toledo, Ohio	Do.
Liberty Sand & Gravel Co	Liberty, Ohio	Liberty, Ohio	Dry; cableway dragline.
Longaker & Hines	Pleasant Hill, Ohio	Near Pleasant Hill, Ohio	Dry; steam shovel.
Marietta Sand Co	Marietta, Ohio	Marietta, Ohio	Wet; ladder dredge.
Marion Sand & Gravel Co	Marion, Ohio	Near Marion, Ohio	Wet; derrick clamshell.

TABLE 1.—Permanent-type commercial sand and gravel plants—Continued.

OHIO—Continued.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Martin & Arnold	New Philadelphia, Ohio	New Philadelphia, Ohio	Dry; steam shovel.
Mount Calvary Sand & Gravel Co	Columbus, Ohio	Columbus, Ohio	Do.
Mulinix Brothers	Toledo, Ohio	Lake near Toledo, Ohio	Wet; pump.
Ohio Gravel Ballast Co	Cincinnati, Ohio	Miami Grove, Ohio	Wet; dipper dredge.
Do	do	Newtown, Ohio	Dry; steam shovel.
Do	do	Cleves, Ohio	Do.
Do	do	Miamiville, Ohio	Do.
Do	do	Trenton, Ohio	Do.
The Ohio River Sand & Gravel Co	do	Cincinnati, Ohio	Wet; pump.
Ohio Valley Sand & Gravel Co	Shadyside, Ohio	Dille, Ohio	Dry; cableway dragline.
David A. Onkst & Son	Dayton, Ohio	Dayton, Ohio	Dry; steam shovel.
G. W. Perry	Washington Courthouse, Ohio	Washington Courthouse, Ohio	Wet; pump.
Port Clinton Lumber & Coal Co	Port Clinton, Ohio	Port Clinton, Ohio	Do.
Portsmouth Sand & Gravel Co	Portsmouth, Ohio	Portsmouth, Ohio	Do.
The Queen City Crushed Stone & Sand Co	Cincinnati, Ohio	Miamiville, Ohio	Dry; steam shovel.
Radebaugh & Grahm	St. Johns, Ohio	St. Johns, Ohio	Do.
The Red Bank Gravel Co	Cincinnati, Ohio	Cincinnati, Ohio	Dry; cableway dragline.
Richwood Sand & Gravel Co	Richwood, Ohio	Gallipolis, Ohio	Wet; derrick clamshell.
Reader Sand & Gravel Co	Canton, Ohio	Canton, Ohio	Dry; locomotive crane clamshell
The River Sand Co	Steubenville, Ohio	Steubenville, Ohio	Wet; ladder dredge.
The Rubber City Sand & Gravel Co	Akron, Ohio	Akron, Ohio	Dry; steam shovel.
John H. Schell	Martins Ferry, Ohio	Martins Ferry, Ohio	Dry; horse scraper.
Steubenville Sand Co	Steubenville, Ohio	Steubenville, Ohio	Dry; steam shovel.
Southern Sand, Gravel & Supply Co	Columbus, Ohio	Columbus, Ohio	Wet; clamshell dredge.
Tarco Construction Co	Cincinnati, Ohio	Cleves, Ohio	Dry; steam shovel.
Do	do	Willeys, Ohio	Do.
Toledo Builders Supply Co	Toledo, Ohio	Maumee River, Toledo, Ohio	Wet; pump.
Toledo Pulp, Plaster & Supply Co	do	do	Do.
Wiggins Sand & Gravel Co	Germantown, Ohio	Germantown, Ohio	Dry; steam shovel.
A. F. Wendling Co	Massillon, Ohio	Massillon, Ohio	Do.
Youngstown Silica Sand Co	Youngstown, Ohio	Youngstown, Ohio	Start operating 1921.
Zanesville Washed Gravel Co	Zanesville, Ohio	Dresden, Ohio	Dry; steam shovel.

KENTUCKY.

Name of producer.	Office address.	Location of plant.	Method of excavation.
J. B. Blanton & Co	Frankfort, Ky	River near Frankfort, Ky	Wet; pump.
Breslin Sand Co	Louisville, Ky	Louisville, Ky	Dry; steam shovel.
T. A. Duke & Co	Maysville, Ky	Near Maysville, Ky	Dry; dragline excavator.
Evansville, Sand & Gravel Co	Henderson, Ky	Henderson, Ky	Dry; report missing.
Grobmyer Sand & Gravel Co	Carrollton, Ky	Carrollton, Ky	Wet; clamshell dredge.
Henderson Sand & Gravel Co	Henderson, Ky	Henderson, Ky	Wet; pump.
Ideal Supply Co	Ludlow, Ky	Ludlow, Ky	Dry; steam shovel.
Kentucky & Ohio Transportation Co	Carrollton, Ky	Carrollton, Ky	Wet; pump.
Memphis Stone & Gravel Co	Memphis, Tenn	Gravel Switch, Ky	Dry; steam shovel.
Nugent Stone Co	Louisville, Ky	River near Louisville, Ky	Wet; pump.
Ohio River Sand & Gravel Co	Paducah, Ky	River near Paducah, Ky	Do.
River Sand & Gravel Co	Owensboro, Ky	River near Owensboro, Ky	Do.
E. T. Slider Co	Louisville, Ky	River near Louisville, Ky	Do.

INDIANA.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Acme Gravel Co	Indianapolis, Ind	Near Indianapolis, Ind	Wet; cableway dragline.
Atlas Sand and Gravel Co	do	do	Do.
B. and B. Sand and Gravel Co	Fort Wayne, Ind	Near Fort Wayne, Ind	Do.
Baker Gravel Co	Noblesville, Ind	Near Noblesville, Ind	Wet and dry; cableway dragline.
Bedford-Nugent Sand and Gravel Co	Evansville, Ind	Near Evansville on L. and N.	Wet; pump.
Bloomfield Washed Sand and Gravel Co	Bloomfield, Ind	Bloomfield, Ind	Do.
Bluffton-Lewisburg Stone Co	Lafayette, Ind	West Lafayette, Ind	Dry; steam shovel.
Brown-Huffstetter Sand Co	Indianapolis, Ind	Near Indianapolis, Ind	Wet and dry; cableway dragline.
Do	do	S. Harding and White River	Do.
Capital City Gravel Co	do	Indianapolis, Ind	Wet; cableway dragline.
Carmichael Gravel Co	Williamsport, Ind	Attica, Ind	Dry; steam shovel.
Do	do	Wolcottville, Ind	Dry; locomotive crane clamshell.
Columbus Gravel Co	Columbus, Ind	Columbus, Ind	Wet; cableway dragline.
Consumers Co	Chicago, Ill	South Bend, Ind	Dry; dragline excavator.
Covington Sand and Gravel Co	Covington, Ind	Covington, Ind	Dry; steam shovel.
Evansville Sand and Gravel Co	Evansville, Ind	Mount Vernon, Ind	Wet; pump.
Do	do	Evansville, Ind	Do.
Granite Gravel Co	Indianapolis, Ind	Indianapolis, Ind	Wet; pump.
Do	do	do	Wet; cableway dragline.
Do	do	do	Wet; Clamshell dredge.
Do	do	Mohawk, Ind	Wet; cableway dragline.
Do	do	Morristown, Ind	Do.
Griffith Sand and Gravel Co	Griffith, Ind	Griffith, Ind	Start operating 1921.
Hazelton Gravel Co	Hazelton, Ind	Hazelton, Ind	Wet; pump.
Abe Hart	Sandborn, Ind	Worthington, Ind	Do.
Do	do	Emison, Ind	Do.
J. M. Hinderleiter	Medora, Ind	Medora, Ind	Do.
George J. Hoffman Co	South Bend, Ind	South Bend, Ind	Dry; derrick clamshell.
Do	do	Near South Bend, Ind	Dry; steam shovel.
Indiana Gravel Co	Indianapolis, Ind	Indianapolis, Ind	Wet; cableway dragline.
Interstate Gravel Co	Terre Haute, Ind	Covington, Ind	Dry; steam shovel.
John Jones and Sons	Indianapolis, Ind	Indianapolis, Ind	Wet; cableway dragline.
Kickapoo Sand and Gravel Co	Attica, Ind	Attica, Ind	Dry; steam shovel.
Kirkpatrick Sand and Gravel Co	Greenfield, Ind	Cambridge City, Ind	Wet; cableway dragline.
Lafayette Hydraulic Gravel Co	Lafayette, Ind	Lafayette, Ind	Dry; steam shovel.
Lennane Brothers	Detroit, Mich	Pleasant Lake, Ind	Dry; dragline excavator.
Macksville Gravel Co	Terre Haute, Ind	Macksville, Ind	Wet; pump.
Martinsville Gravel Co	Martinsville, Ind	Martinsville, Ind	Wet; cableway dragline.
Merom Gravel Co	Indianapolis, Ind	Riverton, Ind	Do.
A. Miller and Sons	Clinton, Ind	Summit Grove, Ind	Dry; steam shovel.
Million Brothers Sand and Gravel Co	Lake Cicott, Ind	Lake Cicott, Ind	Do.
Montezuma Gravel Co	Terre Haute, Ind	Montezuma, Ind	Do.
Montezuma Road and Concrete Gravel Co	Montezuma, Ind	do	Dry; locomotive crane clamshell.
William Nading	Shelbyville, Ind	N. Pike and Blue River	Wet; cableway dragline.
Neal Gravel Co	Matoon, Ill	Attica, Ind	Do.
Do	do	Covington, Ind	Do.
Do	do	Silverwood, Ind	Dry; steam shovel.
Newman and Kirkham Sand and Gravel Co	Lewisville, Ind	Beeson, Ind	Wet; cableway dragline.
Northern Construction Co	Elkhart, Ind	Elkhart, Ind	Do.

TABLE I.—Permanent-type commercial sand and gravel plants—Continued.

INDIANA—Continued.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Northern Indiana Sand and Gravel Co	Wolcottville, Ind	Wolcottville, Ind	Wet and dry; derrick clamshell and steam shovel.
O'Keefe Gravel Co	Plymouth, Ind	Culver, Ind	Wet; pump and cableway dragline.
Richmond-Greenville Gravel Co	Greenville, Ohio	Richmond, Ind	Dry; steam shovel.
Richmond Gravel Co	Richmond, Ind	do	Dry; cableway dragline.
E. T. Slider	New Albany, Ind	New Albany, Ind	Wet; pump.
Standard Sand and Gravel Co	Clinton, Ind	Clinton, Ind	Dry; steam shovel.
Stilwell Sand and Gravel Co	Anderson, Ind	Anderson, Ind	Dry; dragline excavator.
Do	do	Orestes, Ind	Do.
Summit Sand and Gravel Co	Terre Haute, Ind	Terre Haute, Ind	Dry; locomotive crane clamshell.
Do	do	Clinton, Ind	Do.
Wabash Sand and Gravel Co	do	Terre Haute, Ind	Do.
Do	do	Montezuma, Ind	Do.
Wabee Sand and Gravel Co	Milford, Ind	Milford, Ind	Dry; steam shovel.
Warsaw Sand and Gravel Co	Warsaw, Ind	Warsaw, Ind	Do.
Western Indiana Gravel Co	Terre Haute, Ind	Lafayette, Ind	Do.
Do	do	Terre Haute, Ind	Wet; pump.

ILLINOIS.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Ætna Sand & Gravel Co	Chicago, Ill	Algonquin, Ill	Dry; steam shovel.
Anderson-Theobold Co	Vincennes, Ind	Lawrence County, Ill	Wet and dry; dragline excavator.
American Sand & Gravel Co	Chicago, Ill	Carpentersville, Ill	Dry; steam shovel.
Do	do	Antioch, Ill	Do.
Atwood-Davis Sand Co	do	Winnebago County, Ill	Do.
The Barry Sand & Gravel Co	Lincoln, Ill	Near Barry, Ill	Wet; cableway dragline.
Beder Woods Sons Co	Moline, Ill	Moline, Ill	Wet; pump.
Chicago Gravel Co	Chicago, Ill	Plainfield, Ill	Dry; steam shovel.
Do	do	Rockdale, Ill	Do.
Do	do	Spaulding, Ill	Do.
H. D. Conkey	Mendota, Ill	Yorkville, Ill	Do.
Do	do	Oregon, Ill	Wet; pump.
Do	do	Moronts, Ill	Dry; dragline scraper.
Do	do	Sheridan, Ill	Dry; locomotive crane clamshell.
Construction Material Co	Chicago, Ill	Chicago, Ill	Wet; pump.
Decatur Sand & Gravel Co	Decatur, Ill	Decatur, Ill	Do.
R. H. Eastwood Sand & Gravel Co	Grayville, Ill	Grayville, Ill	Do.
Egyptian Gravel Co	St. Louis, Mo	Oliver Branch, Ill	Dry; steam shovel.
Galesburg Sand & Gravel Co	Galesburg, Ill	Buda, Ill	Do.
H. H. Halliday Sand Co	Cairo, Ill	River near Cairo, Ill	Wet; pump.
Illinois Sand & Gravel Co	Marion, Ill	Metropolis, Ill	Do.
Interstate Sand & Gravel Co	Chicago, Ill	Libertyville, Ill	Wet; dragline excavator.
Joliet Gravel Co	Joliet, Ill	Joliet, Ill	Dry; steam shovel.
Keokuk Sand Co	Quincy, Ill	River near Quincy	Wet; pump.
Lake Shore Sand Co	Chicago, Ill	Algonquin, Ill	Dry; steam shovel.
Lincoln Sand & Gravel Co	Lincoln, Ill	Lincoln, Ill	Wet; pump.
Mississippi Lime & Material Co	Alton, Ill	River near Alton, Ill	Do.
Mississippi Sand & Gravel Co	Burlington, Iowa	Keithsburg, Ill	Do.
Missouri Portland Cement Co	St. Louis, Mo	East St. Louis, Ill	Do.
McGrath Sand & Gravel Co	Lincoln, Ill	Forreston, Ill	Dry; cableway dragline.
Do	do	Chillicothe, Ill	Do.
Do	do	Mackinaw, Ill	Do.
Do	do	Pekin, Ill	Do.
Mount Carmel Sand & Gravel Co	Mount Carmel, Ill	River near Mount Carmel, Ill	Wet; pump.
Mount Carmel Elevator Co	do	do	Do.
Moline Consumers Co	Moline, Ill	Moline, Ill	Do.
Do	do	Ottawa, Ill	Wet; derrick clamshell.
Neal Gravel Co	Mattoon, Ill	Palestine, Ill	Wet; pump.
Peoria Washed Sand & Gravel Co	Peoria, Ill	Peoria, Ill	Wet; derrick clamshell.
Pyott Gravel & Sand Co	Chicago, Ill	Algonquin, Ill	Dry; dragline excavator.
Quincy Sand Co	Quincy, Ill	Quincy, Ill	Wet; pump.
Reinert Gravel Co	Chicago, Ill	Algonquin, Ill	Dry; steam shovel.
A. Y. Reed Gravel Co	do	Elgin, Ill	Do.
Richardson Sand Co	do	Carpenterville, Ill	Do.
Do	do	Coleman, Ill	Do.
Rockford Sand & Gravel Co	Rockford, Ill	Rockford, Ill	Dry; mechanical digger.
Do	do	do	Wet; pump.
Rock Island Sand & Gravel Co	Rock Island, Ill	Rock Island, Ill	Do.
Shawneetown Sand & Gravel Co	Shawneetown, Ill	Shawneetown, Ill	Do.
South Elgin Sand & Gravel Co	South Elgin, Ill	South Elgin, Ill	Dry; dragline excavator.
Stoker Gravel & Construction Co	Highland, Ill	Highland, Ill	Dry; mechanical excavator.
Terry & Lewis	Galesburg, Ill	Gladstone, Ill	Wet; pump.
Virginia Timber Co	Springfield, Ill	Springfield, Ill	Do.
Western Sand & Gravel Co	Spring Valley, Ill	Spring Valley, Ill	Dry; dragline scraper.
Yourtee Roberts Sand Co	Chester, Ill	River near Chester, Ill	Wet; pump.

MICHIGAN.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Battjes Fuel & Building Material Co	Grand Rapids, Mich	Grand Rapids, Mich	Dry; derrick clamshell.
Boice Bros	Pontiac, Mich	Pontiac, Mich	Dry; cableway dragline.
Brownlee Park Gravel & Material Co	Battle Creek, Mich	Brownlee Park, Mich	Dry; steam shovel.
G. W. Bunker Co	Grand Rapids, Mich	Wyoming Township, Mich	Dry; dragline excavator.
Burwell Gravel Co	Lansing, Mich	Lansing, Mich	Dry; steam shovel.
Cadillac Builders Supply Co	Detroit, Mich	River near Detroit	Wet; clamshell dredge.
Cadillac Sand & Gravel Co	Ann Arbor, Mich	Geddes, Mich	Dry; steam shovel.
Hugh Campbell & Son	Bay City, Mich	Mason, Mich	Do.
J. Calverts Sons Washing Plant	Detroit, Mich	Clarkson, Mich	Dry; cableway dragline.
Cass City Sand & Gravel Co	Cass City, Mich	Cass City, Mich	Do.
Champion Sand & Gravel Co	Marquette, Mich	Dishneau, Mich	Dry; steam shovel.
Consumers Gravel Co	Detroit, Mich	Detroit, Mich	Wet; pump.
Crescent Gravel Co	Hershey, Mich	Hershey, Mich	Dry; steam shovel.
Detroit-Greenville Gravel Co	Greenville, Ohio	Brighton, Mich	Do.
Detroit-Oxford Gravel & Stone Co	Oxford, Mich	Oxford, Mich	Dry; locomotive crane clamshell.
Detroit Sand & Gravel Co	Detroit, Mich	Utica, Mich	Do.
Federal Sand & Gravel Co	Saginaw, Mich	Evart, Mich	Dry; dragline excavator.
Do	do	Greenbush, Mich	Do.
Do	do	Emerson, Mich	Dry; locomotive crane clamshell.
Do	do	Stinson, Mich	Do.
Genesee Gravel Co	Detroit, Mich	Earlstead, Mich	Wet; cableway dragline.
F. D. Gleason Coal Co	do	Rivers near Detroit	Wet; clamshell dredges (3).
Grand Rapids Gravel Co	Grand Rapids, Mich	Granville Road, Grand Rapids	Dry; steam shovel.
Do	do	Wyoming, Mich	Do.

TABLE 1.—Permanent-type commercial sand and gravel plants—Continued.

MICHIGAN—Continued.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Grand River Washed Sand & Gravel Co.	Ann Arbor, Mich.	Brighton, Mich.	Dry; dragline excavator.
Gohr Bros.	Lansing, Mich.	Millers Road, Lansing.	Dry; locomotive crane clamshell.
Handy Bros. Mining Co.	Bay City, Mich.	Douglas Pit, Mich.	Do.
Harrison Land Co. (Ltd.).	Grand Rapids, Mich.	Grand Rapids, Mich.	Dry; steam shovel.
Heller Bros.	Lansing, Mich.	Lansing, Mich.	Do.
Hershey Gravel Co.	Hershey, Mich.	River near Hershey.	Do.
Ireland & Lester.	Benton Harbor, Mich.	Benton Harbor, Mich.	Wet; pump.
Johnson & Johnson.	Pontiac, Mich.	Pontiac, Mich.	Wet; cableway dragline.
Kalamazoo-Greenville Gravel Co.	Greenville, Ohio.	Kalamazoo, Mich.	Dry; steam shovel.
W. R. Kemp.	Pontiac, Mich.	Pontiac, Mich.	Wet; cableway dragline.
Midland Gravel Co.	Millbrook, Mich.	Millbrook, Mich.	Dry; steam shovel.
Michigan Materials Co.	Muskegon, Mich.	Grand Haven, Mich.	Dry; locomotive crane clamshell.
Michigan Sand & Gravel Co.	Dexter, Mich.	Dexter, Mich.	Dry; derrick clamshell.
Otisville Gravel Co.	Saginaw, Mich.	Otisville, Mich.	Wet; cableway dragline.
Ohio Michigan Sand & Gravel Co.	Toledo, Ohio.	Chilson, Mich.	Dry; steam shovel.
Pfent & O'Brien.	Utica, Mich.	Utica, Mich.	Dry; dragline scraper.
Julius Porath.	Detroit, Mich.	Oxford, Mich.	Dry; cableway dragline.
Puritan Sand & Gravel Co.	do.	Tecumseh, Mich.	Dry; steam shovel and cableway dragline.
Rochester Sand & Brick Co.	do.	Rochester, Mich.	Dry; derrick clamshell.
Standard Gravel Co.	Pontiac, Mich.	New Hudson, Mich.	Dry; cableway dragline.
A. E. Sheltraw.	Saginaw, Mich.	Mason, Mich.	Dry; steam shovels (2).
Superior Sand & Gravel Co.	Detroit, Mich.	River near Detroit.	Wet; pump.
Tecumseh Gravel Co.	Tecumseh, Mich.	Tecumseh, Mich.	Wet and dry; cableway dragline and steam shovel.
Tuscola Sand & Gravel Co.	Cass City, Mich.	Cass City, Mich.	Dry; cableway dragline.
United Fuel & Supply Co.	Detroit, Mich.	Oxford, Mich.	Dry and wet; cableway dragline.
Do.	do.	Detroit, Mich.	Wet; pump.
Do.	do.	New Hudson, Mich.	Wet; cableway dragline.
Valley City Sand & Gravel Co.	Grand Rapids, Mich.	Kelly Siding, Mich.	Dry; dragline excavator.
Isaac Van Weelden.	Grand Haven, Mich.	River near Grand Haven.	Wet; dragline excavator.
Ward Sand & Gravel Co.	Detroit, Mich.	Oxford, Mich.	Wet; cableway dragline.
Do.	do.	do.	Wet; pump.
Hoyt Woodman.	Lansing, Mich.	Lansing, Mich.	Dry; horse scraper.
Ypsilanti Sand & Gravel Co.	Ypsilanti, Mich.	Ypsilanti, Mich.	Dry; steam shovel.

WISCONSIN.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Beloit Sand & Gravel Co.	Janesville, Wis.	Riton, Wis.	Dry; mechanical digger.
Big Bend Sand & Gravel Co.	Big Bend, Wis.	Big Bend, Wis.	Dry; cableway dragline.
Casco Gravel Co.	Green Bay, Wis.	Casco Junction, Wis.	Dry; dragline scraper.
Cast Stone Construction Co.	Eau Claire, Wis.	Shawtown, Wis.	Dry; dragline excavator.
Cook & Brown Lime Co.	Oshkosh, Wis.	Lake Beaumont, Wis.	Dry; steam shovel.
J. Donahue & Sons.	Milwaukee, Wis.	Waukesha, Wis.	Do.
Elkhart Lake Sand & Gravel Co.	Elkhart Lake, Wis.	Elkhart Lake (3 plants).	Dry; dragline scraper.
Eau Claire Sand & Gravel Co.	Eau Claire, Wis.	Shawtown, Wis.	Dry; derrick clamshell.
Federal Sand & Gravel Co.	Chicago, Ill.	Beloit, Wis.	Dry; steam shovel.
Do.	do.	Janesville, Wis.	Do.
Grand Rapids Sand & Gravel Co.	Grand Rapids, Wis.	Bosserton, Wis.	Dry; horse scraper.
Hayworth Sand & Gravel Co.	Milwaukee, Wis.	Lapham, Wis.	Dry; mechanical digger.
J. G. James Sand & Gravel Co.	do.	Milwaukee, Wis.	Do.
Janesville Sand & Gravel Co.	Janesville, Wis.	Janesville, Wis. (3 plants).	Do.
Lincoln Gravel Co.	Tomahawk, Wis.	Tomahawk, Wis.	Dry; steam shovel.
Moraine Gravel Co.	Plymouth, Wis.	Glenbeulah, Wis.	Do.
Northern Gravel Co.	Chicago, Ill.	Barton, Wis.	Do.
Racine County Sand & Gravel Works.	Racine, Wis.	Burlington, Wis.	Dry; dragline scraper.
Rasmussen-Ebbe Sand & Gravel Co.	Waupaca, Wis.	Waupaca, Wis.	Wet; cableway dragline.
Reed Sand & Gravel Co.	Burlington, Wis.	Burlington, Wis.	Dry; cableway dragline.
Stevens Point Sand & Gravel Co.	Stevens Point, Wis.	Rocky Run, Wis.	Wet; cableway dragline.
Waukesha Lime & Stone Co.	Waukesha, Wis.	Waukesha, Wis.	Dry; steam shovel.
Waukesha Washed Sand & Gravel Co.	do.	do.	Wet and dry; cableway dragline and steam shovel.
Do.	do.	Okauchee, Wis.	Dry; cableway dragline.
Waupaca Sand & Gravel Co.	Waupaca, Wis.	Amherst Junction, Wis.	Do.
Wausau Sand & Gravel Co.	Wausau, Wis.	Wausau, Wis.	Do.
Whitney Bros.	Superior, Wis.	Superior, Wis.	Wet; pump.
Wilcox Sand & Gravel Co.	Chicago, Ill.	Janesville, Wis.	Do.
Do.	do.	Fontana, Wis.	Dry; steam shovel.
Wisconsin Sand & Gravel Co.	Milwaukee, Wis.	North Lake, Wis.	Do.
Wissota Sand & Gravel Co.	Eau Claire, Wis.	Anson, Wis.	Dry; dragline excavator.

MINNESOTA.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Barnett & Record.	Duluth, Minn.	Lake Superior.	Wet; pump.
Best Construction Co.	Rochester, Minn.	Near Rochester, Minn.	Dry; derrick clamshell.
Biesanz Stone Co.	Winona, Minn.	Near Winona, Minn.	Wet; dragline excavators (2).
Biwabik Sand & Gravel Co.	Biwabik, Minn.	Biwabik, Minn.	Dry; steam shovel.
Blue Limestone Co.	Minneapolis, Minn.	Minneapolis, Minn.	Do.
Casey & Co.	do.	do.	Dry; dragline excavator.
Foley Bros.	St. Paul, Minn.	New London, Minn.	Dry; cableway dragline.
D. W. Harding & Co.	Minneapolis, Minn.	Golden Valley, Minn.	Dry; dragline scraper.
Kasota Sand & Gravel Co.	Kasota, Minn.	Kasota, Minn.	Dry; cableway dragline.
Landers-Morrison-Christenson Co.	Minneapolis, Minn.	Near Minneapolis, Minn.	Do.
W. H. Malone Co.	St. Paul, Minn.	St. Paul, Minn.	Dry; horse scrapers.
Marshall Concrete Tile Co.	Marshall, Minn.	Russell, Minn.	Dry; steam shovel.
C. E. Mason & Co.	Minneapolis, Minn.	Minneapolis, Minn.	Dry; dragline scraper.
Medford Washed Sand & Gravel Co.	Medford, Minn.	Medford, Minn.	Dry; cableway dragline.
Minnesota Gravel Co.	Springfield, Minn.	Courtland, Minn.	Dry; plant planned.
Minnesota Pipe & Tile Co.	Mankato, Minn.	Appleton, Minn.	Wet; pump.
Do.	do.	Mankato, Minn.	Do.
National Concrete Materials Co.	Luverne, Minn.	Luverne, Minn.	Do.
S. J. Peterson Sand & Gravel Co.	Minneapolis, Minn.	Minneapolis, Minn.	Dry; mechanical digger.
Randolph Sand & Gravel Co.	St. Paul, Minn.	Randolph, Minn.	Wet and dry; pump, cableway dragline, and steam shovel.
River Sand & Gravel Co.	Winona, Minn.	Winona, Minn.	Wet; pump.
J. L. Shiely Co.	St. Paul, Minn.	St. Paul, Minn.	Dry; steam shovel.
The A. M. Smith Sand & Gravel Co.	Minneapolis, Minn.	Golden Valley, Minn.	Do.
Stiefel Material Co.	St. Paul, Minn.	St. Paul, Minn.	Dry; mechanical digger.
United Materials Co.	do.	do.	Dry; steam shovel.
Winona Sand & Gravel Co.	Winona, Minn.	Winona, Minn.	Wet; cableway dragline.
Zenith Concrete Gravel Co.	Carlton, Minn.	Carlton, Minn.	Dry; steam shovel.

TABLE 1.—Permanent-type commercial sand and gravel plants—Continued.

IOWA.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Automatic Gravel Products Co	Muscatine, Iowa	Muscatine, Iowa	Wet; cableway dragline.
Bartlett & McFarland	Waterloo, Iowa	River near Waterloo	Do.
Frank Beutin Sand & Gravel Co	Dubuque, Iowa	Dubuque, Iowa	Wet; pump.
Big Sioux Sand & Gravel Co	Akron, Iowa	Akron, Iowa	Dry; cableway dragline.
John Brooks Sand & Gravel Co	Waverly, Iowa	Shellrock, Iowa	Dry; horse scraper.
Builders Sand & Gravel Co	Davenport, Iowa	River near Davenport	Wet; pump.
Burlington Sand & Gravel Co	Muscatine, Iowa	River near Muscatine	Do.
Capital City Sand Co	Des Moines, Iowa	River near Des Moines	Do.
Cedar River Sand & Material Co	Waterloo, Iowa	7 miles east of Waterloo, Iowa	Do.
City Sand & Gravel Co	Iowa City, Iowa	River near Iowa City	Do.
Clermont Brick & Sand Co	Clermont, Iowa	Clermont, Iowa	Dry; steam shovel.
Clinton Sand & Gravel Co	Clinton, Iowa	Clinton, Iowa	Wet; pump.
Coon River Sand Co	Des Moines, Iowa	River near Des Moines	Do.
Frank Cramm & Sons	do	do	Do.
Des Moines Building Material Co	do	do	Do.
Des Moines Sand & Fuel Co	do	do	Do.
Eddyville Sand & Gravel Co	Eddyville, Iowa	Near Eddyville, Iowa	Dry; drag-line excavator.
Flint Crushed Gravel Co	Des Moines, Iowa	Porter, Iowa	Do.
M. J. Gilleas Co	Cherokee, Iowa	3 miles north of Cherokee, Iowa	Dry; locomotive crane clamshell.
Graettinger Tile Co	Graettinger, Iowa	Graettinger, Iowa	Dry; cableway drag line.
Hahn-Muscatine Co	Muscatine, Iowa	Muscatine, Iowa	Wet; pump.
Harvey Sand & Gravel Co	Harvey, Iowa	River near Harvey, Iowa	Wet; cableway drag line.
Hayden Sand & Gravel Co	Rock Valley, Iowa	Rock Valley, Iowa	Dry; steam shovel.
Hills Sand & Gravel Co	Hills, Iowa	Hills, Iowa	Wet; cableway drag line and pump.
W. Horrabin	Iowa City, Iowa	5 miles south of Iowa City, Iowa	Wet; pump.
Humboldt Gravel & Tile Co	Humboldt, Iowa	3 miles south of Humboldt, Iowa	Dry; locomotive crane clamshell.
Ideal Sand & Gravel Co	Mason City, Iowa	Near Mason City, Iowa	Dry; drag-line excavators (2).
Independent Sand & Gravel Co	Des Moines, Iowa	River near Des Moines	Wet; pump.
Interstate Material Co	Davenport, Iowa	Davenport, Iowa	Do.
Iowa Sand & Gravel Co	Oskaloosa, Iowa	River near Oskaloosa	Do.
Johnston Bros. Clay Works	Fort Dodge, Iowa	Clay Works, Iowa	Dry; steam shovel.
Kelly Sand & Fuel Co	Burlington, Iowa	River near Burlington	Wet; pump.
J. J. Kemp Sand & Gravel Co	Oyens, Iowa	Oyens, Iowa	Do.
Keokuk Sand Co	Keokuk, Iowa	River near Keokuk, Iowa	Do.
Kings Crown Plaster Co	Cedar Rapids, Iowa	River near Cedar Rapids	Do.
Lake View Sand & Gravel Co	Lake View, Iowa	Lake View, Iowa	Do.
Do	do	do	Wet; pump and cableway dragline.
Langworthy Silica Co	Dubuque, Iowa	Clayton, Iowa	Dry; steam shovel.
Larimer & Shaffer Sand Co	Cedar Rapids, Iowa	Cedar Rapids, Iowa	Wet; pump.
Le Mars Gravel Co	Le Mars, Iowa	Le Mars, Iowa	Do.
Do	do	Cherokee, Iowa	Dry; cableway drag line.
Do	do	Hawarden, Iowa	Wet; pump.
Do	do	Doon, Iowa	Do.
McHose Sand & Tile Co	Boone, Iowa	Fraser, Iowa	Wet; pumps (2).
Miller Sand Co	Doon, Iowa	Doon, Iowa	Dry; horse scrapers.
Mole Sand & Gravel Co	Dubuque, Iowa	Dubuque, Iowa	Wet; pump.
Muscatine Sand & Gravel Co	Muscatine, Iowa	River near Muscatine	Do.
National Concrete Materials Co	Sioux City, Iowa	Akron, Iowa	Wet; cableway dragline.
Niles Sand & Gravel Co	Charles City, Iowa	Nilesville, Iowa	Wet; pump.
Northern Gravel Co	Muscatine, Iowa	Muscatine, Iowa	Do.
C. A. Oehlerking	Hawarden, Iowa	Hawarden, Iowa	Wet; drag-line excavator.
Oak Park Sand Co	Des Moines, Iowa	Valley Junction, Iowa	Wet; pump.
Ottumwa Sand Co	Ottumwa, Iowa	1 mile west of Ottumwa, Iowa	Do.
Pearl City Gravel Co	Muscatine, Iowa	3 miles south of Muscatine	Do.
Portland Sand & Gravel Co	Des Moines, Iowa	Valley Junction, Iowa	Do.
Do	do	Booneville, Iowa	Do.
Reliance Sand & Gravel Co	do	3½ miles Des Moines, Iowa	Dry; derrick clamshell.
Remsen Sand & Gravel Co	Remsen, Iowa	Remsen, Iowa	Wet; pump.
Do	do	Correctionville, Iowa	Dry; locomotive crane clamshell.
Sabula Sand & Gravel Co	Lincoln, Ill.	Sabula, Iowa	Wet; pump.
Saction Sand & Gravel Co	Lake View, Iowa	Saction, Iowa	Dry; cableway drag line.
Schneider Sand & Gravel Co	Clinton, Iowa	Clinton, Iowa	Wet; pump.
J. M. Smith Sand Co	Cedar Falls, Iowa	Cedar Falls, Iowa	Wet; cableway drag line.
Spencer Washed Sand & Gravel Co	Spencer, Iowa	Spencer, Iowa	Wet; pump.
Standard Sand & Gravel Co	Oskaloosa, Iowa	Harvey, Iowa	Do.
Wapelle Sand & Building Material Co	Ottumwa, Iowa	River near Ottumwa	Do.
Waterloo Dredging Co	Waterloo, Iowa	River near Waterloo	Wet; cableway drag line.
Woodbury County Gravel Works	Correctionville, Iowa	Correctionville, Iowa	Plant not completed.

TABLE 2.—Permanent-type commercial sand and gravel plants in twenty-two north central and north eastern States.

State.	Number of plants.				Daily capacity, tons.	1919, tonnage.	1920, estimated tonnage.	Increased, tons.	Decreased, tons.	1920, tons used on roads.	Claims of car shortage effect on production at various plants.			
											1919		1920	
	Total.	Wet.[1]	Dry.[1]	Both.							Number affected.	Per cent reduced.	Number affected.	Per cent reduced.
Maine	3		3		900	57,000	77,000	20,000		9,200	0		1	50
New Hampshire	1		1		210	30,000	35,000	5,000		5,250	0		1	15
Vermont[2]	0													
Massachusetts	12	1	11		9,885	674,000	968,000	294,000		147,600	0		3	20 to 70
Rhode Island[2]	0													
Connecticut	10	2	8		2,750	326,000	360,500	34,500		69,850	0		1	90
New York	26	6	20		28,615	2,867,600	3,469,700	602,100		846,850	5	25 to 60	9	15 to 75
New Jersey	25	5	18	2	26,425	1,967,000	2,352,000	395,000		956,850	15	5 to 75	15	5 to 75
Pennsylvania	50	18	32		50,200	4,936,000	5,633,200	697,200		1,229,650	19	10 to 50	26	10 to 75
Delaware	2		2		700	60,000	44,000		16,000	26,000	2	25 to 50	2	50
Maryland and District of Columbia	10	3	7		12,250	1,907,000	1,802,170		104,830	470,100	7	10 to 33	7	10 to 40
Virginia	14	3	11		17,650	1,101,000	1,046,900		54,100	356,000	7	15 to 80	11	25 to 60
West Virginia	18	13	5		10,000	465,400	526,400	61,000		216,500	13	10 to 90	16	10 to 90
Ohio	78	33	43	2	71,120	4,287,150	5,369,500	1,082,350		1,818,125	36	5 to 80	40	10 to 90
Kentucky	12	10	2		14,040	877,750	1,089,750	212,000		180,800	6	25 to 50	5	20 to 60
Indiana	63	33	30		59,825	4,380,400	4,225,500		154,900	1,687,800	29	10 to 95	33	15 to 95
Illinois	51	22	27	2	79,225	5,467,800	5,425,000		42,800	2,944,000	35	6 to 85	38	20 to 90
Michigan	51	20	31		59,415	4,320,085	4,847,000	526,915		1,403,565	32	10 to 75	39	10 to 90
Wisconsin	35	3	32		33,750	1,979,942	3,211,000	1,231,058		883,700	17	10 to 60	18	25 to 90
Minnesota	32	6	26		20,835	838,964	1,676,000	837,036		497,700	8	30 to 70	11	40 to 90
South Dakota	3		3		2,400	(3)	78,000			25,000	0		0	
Iowa	71	42	29		57,540	2,055,873	2,661,000	605,127		642,000	38	10 to 80	49	20 to 85
	567	220	341	6	557,735	38,598,964	44,897,620	6,593,286	372,630	14,416,540	269	5 to 95	325	5 to 95

[1] Wet and Dry, as used here, apply only to excavation and not to screening method.
[2] Local pits only.
[3] Started 1920.

In the statistics above, small, locally used sand and gravel pits are not included. These, however, are abundant, especially in the northern States.

TABLE 3.—Showing number of plants using various sand and gravel excavation methods.

State.	Dry excavation.						Dry or wet excavation.			Wet excavation.				No report.	Total plants.	Total of all methods at all plants.
					Clamshell.		Drag line.				Dredges.					
	Steam shovel.	Mechanical digger.	Horse scraper.	Hand.	Derrick.	Locomotive crane.	Cableway.	Excavator.	Scraper.	Pump.	Ladder.	Dipper.	Clamshell.			
Maine	2														2	2
New Hampshire	1														1	1
Vermont[1]																
Massachusetts	5				1	4		1		1					12	12
Rhode Island[1]																
Connecticut	1				1	1		3					1		7	7
New York	8	1			3	2	1			4	1		1		20	21
New Jersey	11	1			3	1	1			5	2				24	24
Pennsylvania	11			4		1	5			10	10	1			41	42
Delaware					1										1	1
Maryland and District of Columbia	3				1						3				7	7
Virginia	2						2	5		4					13	13
West Virginia	1		1		3		1			7	7	1			20	21
Ohio	27		2	1	2	4	8	1		18	3	2	1	2	69	71
Kentucky	3							1		7			1	1	13	13
Indiana	17				2	6	23	4		13			1	1	65	67
Illinois	16	2			2	1	5	4	2	23					55	55
Michigan	19		1		3	7	15	6	1	5			2		57	59
Wisconsin	11	4	1		1		8	2	3	1			1		31	32
Minnesota	7	2	1		1		6	2	2	5			1	1	27	28
South Dakota	1						1		1						3	3
Iowa	4		2		1	3	12	4		43				1	68	70
Total	150	10	8	5	25	30	88	33	9	146	26	4	9	6	536	549

[1] Locally used pits only.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN MARCH, 1921.

State.	Project No.	County.	Length, in miles.	Type of construction.	Project statement approved.	Total estimate.	Federal aid.
Arizona	44	Mohave	0.500	Gravel	Mar. 17	$12,295.25	$6,147.62
Arkansas	62	Washington	[1].150	do	Mar. 25	[1] 4,115.54	
	121	Phillips	9.080	Concrete	Mar. 11	233,789.49	60,000.00
	126	Saline	5.400	Gravel	Mar. 25	16,114.15	7,500.00
	128	Cleveland	6.570	do	do	30,380.02	10,000.00
	131	White	4.080	do	do	50,490.35	24,000.00
	132	Pope	4.250	Macadam	Mar. 26	80,176.99	30,000.00
California	66	Amador	5.860	Earth	do	49,995.00	24,997.50
	67	Sacramento	8.440	do	do	112,530.00	56,265.00
Colorado	103	San Miguel	5.000	do	Mar. 19	29,365.60	14,682.80
	104	Montrose		Bridge	Mar. 25	33,044.00	16,522.00
	180	Costilla	2.135	Earth	Mar. 2	20,403.24	10,201.62
	183	Mesa	.997	Concrete	Mar. 25	46,093.98	19,940.00
	184	do	.806	do	Mar. 11	39,995.89	16,120.00
	190	Summit	1.017	Earth	Mar. 23	30,988.38	15,494.19
Georgia	212	Ware	11.360	do	Mar. 25	100,000.01	50,000.00
	219	Washington		Bridge	Mar. 2	60,698.00	30,000.00
	223	Appling	4.503	Sand-clay	Mar. 25	39,667.47	19,833.73
	224	Gordon	2.500	do	Mar. 23	28,694.60	14,347.30
Kansas	56	Grady	[3] 6.000	Gravel	Mar. 26	[3] 69,991.90	[3] 28,750.00
Kentucky	40	Muhlenburg	27.700	do	Mar. 3	550,206.25	275,103.12
	47	Hopkins	20.800	Gravel and macadam	Mar. 23	489,225.00	244,612.50
	50	Jefferson	8.650	Concrete	do	406,456.32	173,000.00
	57	Bell	1.511	Earth	Mar. 25	22,332.20	11,166.10
Louisiana	32	Grant	[1] 15.510	Gravel	Mar. 17	[1] 182,546.53	[1] 91,273.26
Maine	17	Piscataquis	[3] 2.060	do	Feb. 28	[3] 30,580.55	[3] 15,290.27
Minnesota	168	Itasca	[3] 8.430	Concrete brick or asphaltic	Feb. 14	[3] 346,568.64	[3] 168,600.00
	190	St. Louis	1.510	Gravel	Feb. 25	33,803.00	16,000.00
	200	Big Stone	2.250	do	Feb. 23	23,067.00	7,000.00
	202	St. Louis	2.080	Brick, concrete, or asphalt	Feb. 25	120,204.48	38,000.00
	204	Itasca	6.460	Gravel	Feb. 29	100,199.22	10,000.00
Mississippi	91	Simpson	12.760	Gravel	Feb. 11	121,952.82	60,976.41
	109	Pike	.980	do	Feb. 17	15,178.24	7,589.12
	114	Grenada	14.800	do	Feb. 11	192,612.64	75,000.00
	115	Hinds	5.830	Concrete, brick, or asphalt	Feb. 25	221,633.50	100,000.00
Missouri	182	Newton	9.940	Gravel and chat	Feb. 19	52,833.04	26,416.52
Montana	152	Phillips	8.000	Gravel	Feb. 23	60,225.00	30,112.50
	155	Valley	5.000	do	Feb. 17	39,600.00	19,800.00
Nebraska	143	Polk, York, and Fillmore	[2].400	Earth	Feb. 19		
North Dakota	124	Barnes	[2] 2.500	do	Feb. 14	[2] 17,930.00	[2] 8,965.00
Ohio	128	Montgomery	1.633	Concrete or bituminous macadam	Feb. 25	70,000.00	20,000.00
Oklahoma	6	Okmulgee	[3] 15.000	Bituminous macadam	Feb. 7	[3] 183,717.60	[3] 91,858.80
Oregon	20	Wasco	[3] 11.5	Concrete or asphalt on concrete base	do	[3] 285,000.00	[3] 117,500.00
South Carolina	85	Williams and Berkeley		Bridge	Feb. 11	848,309.00	424,154.50
	101	Florence and Marion		do	Mar. 3	349,670.20	150,000.00
	106	Richland and Sumter		do	Mar. 25	149,881.05	74,940.52
	114	Greenville	.865	Topsoil	Mar. 2	9,457.80	4,728.90
South Dakota	62	McCook	14.000	Gravel	Mar. 23	97,834.00	48,917.00
	73	Campbell	12.196	Earth	Mar. 19	59,200.68	29,600.34
	75	Perkins	8.640	do	Mar. 2	41,197.75	20,598.87
Texas	16	McColloch	[3] 37.400	Gravel and sand-clay	Mar. 6	[3] 75,774.60	[3] 35,000.00
	212	Val Verde	7.290	Gravel	Mar. 3	50,759.94	25,000.00
	224	Shelby	35.500	do	Mar. 2	428,409.76	100,000.00
	235	Howard, Midland, Martin, and Ector	95.00	do	Mar. 11	877,264.41	302,279.00
	236	Washington	33.000	do	Mar. 23	963,228.20	200,000.00
Utah	27	Cache	[3] 10.450	Concrete	Mar. 12	[3] 291,280.25	[3] 145,640.12
Vermont	23	Bennington	.890	do	Mar. 22	39,297.50	19,648.75
Virginia	99	Halifax and Pittsylvania	6.220	Topsoil	Mar. 7	40,418.40	20,209.20
Wisconsin	119	Barron	.727	Earth	Mar. 21	16,329.17	8,000.00
	130	Price	[1] 2.430	do	Mar. 14	[1] 20,509.94	[1] 9,922.02
	181	Dane	3.000	do	Mar. 23	38,822.68	13,000.00
	191	Clark	.470	Gravel	Mar. 29	19,125.70	7,500.00
	195	Columbia	3.310	do	Mar. 8	30,000.00	12,000.00
	197	Dane	3.310	Earth	do	39,259.17	17,000.00
	199	do	5.360	Gravel	Mar. 11	49,500.00	16,500.00
	207	Forest	4.850	do	Mar. 8	64,650.22	24,000.00
	212	Iron	5.540	do	Mar. 23	58,874.82	20,000.00
	222	Langlade	5.640	do	Mar. 8	71,315.41	25,000.00
	227	Marquette	1.636	do	do	31,468.88	11,500.00
	232	Outagamie	2.350	Concrete	do	102,551.79	42,000.00
	233	Pepin	2.150	Shale and gravel	do	14,997.40	6,000.00
	255	Manitowoc	3.670	Concrete	do	146,159.74	50,109.12

[1] Revised statement. Amounts given are increases over those in the original statement.
[2] Revised statement. Amounts given are decreases over those in the original statement.
[3] Withdrawn.

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